No. FHWA-RD-78-139

USER'S MANUAL: FHWA HIGHWAY TRAFFIC NOISE PREDICTION MODEL, SNAP 1.0

January 1979

Final Report

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Springfield, Virginia 22161

Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D. C. 20590

FOREWORD

This report is a user's manual for a computer program, SNAP 1.0, that has been developed for predicting traffic noise impacts and will be of interest to traffic noise specialists involved in assessing traffic noise impacts and evaluating alternative traffic noise mitigation strategies.

Research in highway noise and vibration is included in the Federally Coordinated Program of Highway Research and Development as Task 4 of Project 3F, "Pollution Reduction and Environmental Enhancement." Dr. Howard Jongedyk is the Project Manager and Dr. Timothy M. Barry is the Task Manager.

The traffic noise model on which this computer program was based was developed by the Federal Highway Administration and is documented in FHWA report, FHWA-RD-77-108, "FHWA Highway Traffic Noise Prediction Method" which is available from the National Technical Information Service, Springfield, Virginia 22161.

Sufficient copies of this report are being distributed to provide a minimum of two copies to each FHWA regional office, and one copy to each FHWA division office and State highway agency. Direct distribution is being made to the division offices.

Charles F. Scheffey
Director, Office of Research

NOTICE

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-78-139		

4. Title and Subtitle	5. Report Date
USER'S MANUAL FHWA HIGHWAY TRAFFIC NOISE PREDICTION MODEL SNAP 1.0	January 1979
	6. Performing Organization Code
7. Author(s) F.F. RUDDER, JR. and D.F. LAM	8. Performing Organization Report No. 5-451-00-066-05
9. Performing Organization Name and Address Science Applications, Inc. Energy & Environmental Sciences Division 1651 Old Meadow Rd., McLean, VA 22102	10. Work Unit No.
	11. Contract or Grant No. DOT-FH-11-9384
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration Office of Research, Environmental Design and Control Washington, DC 20590	13. Type of Report and Period Covered Final Report Dec. 1977-July 1979
	14. Sponsoring Agency Code

15. Supplementary Notes

Contract Manager: Dr. T.M. Barry

16. Abstract

This report describes the FHWA Level 1 Highway Traffic Noise Prediction Model. This model is given the acronym "SNAP 1.0" for Simplified Noise Analysis Program 1.0. The model is designed to allow the quick calculation of highway traffic noise emissions for simple roadway-receiver configurations. All computed output is presented in tabular format for direct inclusion in reports.

The report describes the formulation of input data, input data format, and the predicted traffic noise estimates. Barrier attenuation is considered for traffic lanes parallel to the barrier. Both "thin screen" and "berm" type barriers are considered by the model. Vehicle noise emissions are estimated by vehicle type and vehicle speed.

17. Key Words	18. Distribution Statement
Highway Traffic Noise Prediction Highway Traffic Noise Abatement Highway Noise Barrier Design	Document is available to the public through: National Technical Information Service Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	144	

Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

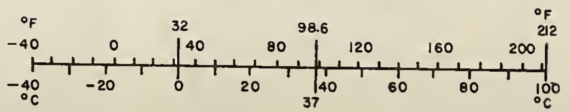
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The FHWA Level 1 highway traffic noise prediction program is one part of a continuing effort to refine and improve engineering methods for the prediction of traffic-generated noise. The computer program described in this report is based upon the theory of Reference 1 and is a model designed to allow the user to predict quickly traffic noise impacts for simple roadway-receiver geometries. The FHWA Level 1 program is given the acronym SNAP 1.0 for Simplified Noise Analysis Program. SNAP predicts the equivalent sound level metric, L_{eq}, and approximates the L_{10} percentile sound level for constant speed traffic flows comprising a mix of vehicle types.

SNAP allows the user to formulate site geometry using lateral, longitudinal, and vertical coordinates rather than distances and angles as measured from a receiver. This formulation for site geometry was selected so that site geometry defining traffic lanes and a barrier location need only be defined once. The user may then define as many locations for receivers as desired without redefining the traffic lanes and the barrier location.

The theory of barrier noise attenuation used for SNAP calculations assumes that traffic lanes are parallel to the top edge of the barrier. This means that for traffic noise predictions with barrier attenuation, <u>all</u> traffic lanes must be parallel to each other and parallel to the barrier. Lanes, however, may be placed at different elevations. If the user desires predictions without barrier attenuation, SNAP allows the user to model accurately curved roadways. However, each lane must be at a constant elevation. SNAP most accurately models sites that are essentially flat.

The FHWA Level 1 program is described in this user's manual. The main text is devoted to a discussion of problem formulation using the SNAP 1.0 program and the interpretation of the various output predictions. Appendices that document the program are included.

If the user decides that SNAP 1.0 cannot accurately define the site geometry associated with a given problem, the user may wish to consider the FHWA Level 2 highway traffic noise prediction model (2)*.

*Numbers in ( ) in the text denote references listed at the end of the report.

2.0 PREDICTION OF HIGHWAY TRAFFIC NOISE: SNAP 1.0

2.1 Overview of Problem Definition

SNAP allows the user to predict highway traffic noise considering the following:

- Multi-lane Highways - A maximum of 12 parallel traffic lanes each described by a speed and a mix of vehicles are allowed.
- Vehicle Types - Three code-defined vehicles and one optional user-defined vehicle with speed-dependent noise emission characteristics may be defined.
- Sound Level Adjustments - The user may define constant sound level adjustments for each vehicle type on each lane to simulate, for example, noise emissions due to traffic on grades.
- Barrier Attenuation - The optional specification of a single barrier with the top edge parallel to the traffic lanes is allowed. Either "thin screen" or "berm" attenuation may be selected.
- Excess Distance Attenuation - For each lane-receiver combination, the user may define an excess distance attenuation parameter to simulate site acoustic characteristics.
- Unlimited Number of Receiver Locations - For a given roadway-barrier configuration, traffic noise predictions are conducted for as many receiver locations as the user specifies.
- Tabulated Output - For each receiver location, tabulations of the sound level contributions from each vehicle type on each traffic lane with subtotals by vehicle type and by lane are presented. These tabulations allow the user to estimate barrier noise abatement effectiveness both by vehicle type and traffic lane. The tabulations may be directly included in a report without photo reduction.

2.2 Multi-Lane Highways

SNAP 1.0 allows the user to specify a maximum of 12 traffic lanes to simulate a roadway configuration. Each lane is geometrically described as a constant elevation (z coordinate) straight line segment.

The orientation of the lane in the horizontal plane is defined by specifying the (x,y) coordinates of each end point of the lane.

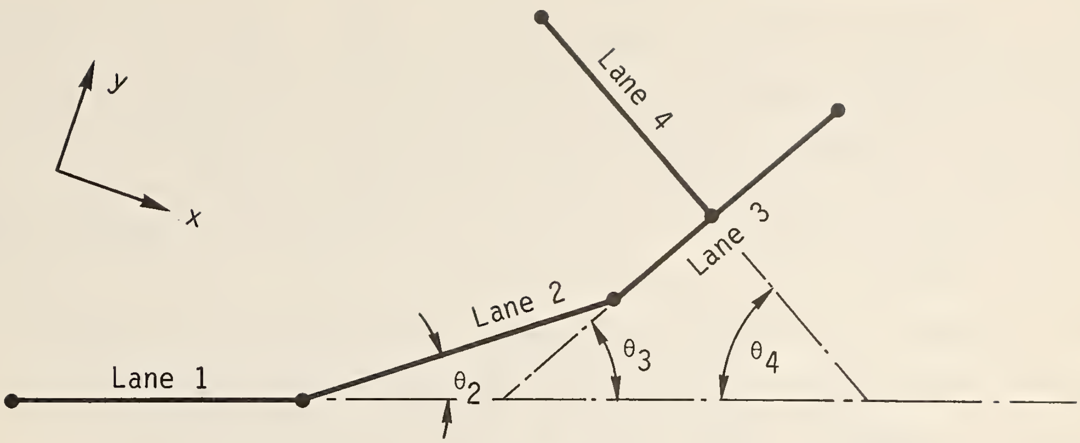
SNAP 1.0 assumes that each lane is parallel to the defined location of a barrier. If the problem does not require barrier attenuation calculations, the theory upon which SNAP 1.0 is based allows the user to simulate non-parallel traffic lanes. Additionally, it is recognized that depending upon the available site data and/or estimating end points from map coordinates, the specification of exactly parallel line segments may be difficult. To allow the user the freedom of specifying either non-parallel lanes (no barrier attenuation) or to establish an engineering tolerance for parallel line segments, SNAP 1.0 defines a criterion for parallelism.

The criterion for parallelism is specified as the maximum allowable angular deviation, expressed in degrees, between two straight line segments as measured in the horizontal (x,y) plane. Line segments that are exactly parallel are specified by a criterion of 0.0°. Non-parallel lines are specified by an appropriate angle up to 90° maximum. The concept of specifying this criterion is illustrated in Figure 2-1.

The user must exercise engineering judgement in specifying the maximum allowable angular deviation. For barrier attenuation calculations, the angular deviation should be as small as practical*. If the user does not define a barrier for a problem, he may specify the angular deviation as 90° and orient the lanes as desired. SNAP 1.0 will terminate execution if any two line segments are specified with a relative angular deviation exceeding the criterion value.

The geometric specification of traffic lanes allows the user to define lanes that coincide in location. This feature allows the user to define traffic flows at different speeds and vehicle mixes based upon the concept of an "equivalent" lane distance (1).

*See Appendix A, Section A.2, pp. A-4 to A-7 and Eqn (A-5a)

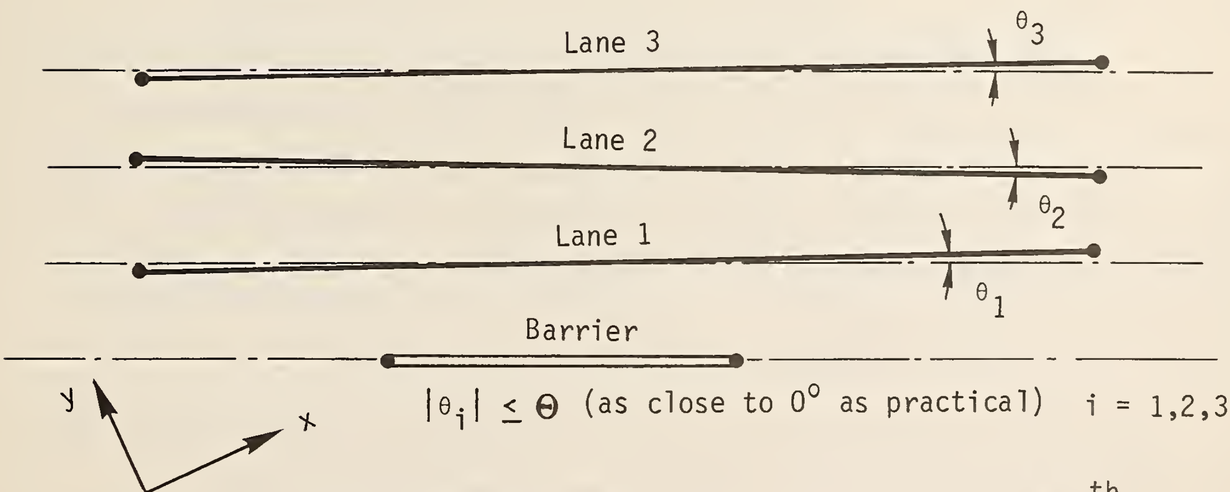


$|\theta_i| \leq \Theta \quad i = 2,3,4$

θ_i is calculated from the (x,y) coordinates of the i^{th} lane end points relative to lane 1

Θ is the criterion for parallelism (angle in degrees; 90^{o} max.)

(a) Non-Parallel Lanes for Sites without a Barrier



$|\theta_i| \leq \Theta$ (as close to 0^{o} as practical) $\quad i = 1,2,3$

θ_i is calculated from the (x,y) coordinates of the i^{th} lane end points relative to the barrier

Θ is the criterion for parallelism (angle in degrees; as close to zero as practical)

(b) Parallel Lanes for Sites with a Barrier

FIGURE 2-1 SPECIFICATION OF CRITERION FOR PARALLELISM

2.3 Vehicle Types

The formulation of the SNAP 1.0 model requires the definition of traffic flow conditions on each lane for a specified time period. That is, all traffic flow data for all lanes must correspond to the same time period. The sound level metrics estimated by SNAP 1.0 are L_{eq} and L_{10}, for the time period T. Hence, the user may use half-hourly, hourly, or daily (24-hour) data, as desired and SNAP 1.0 will calculate the traffic noise estimates accordingly. Generally, the user will desire "worst-hour" traffic noise levels. In this case, the hourly data describing lane speed and vehicle count (by vehicle type and lane) are used as input.

For each lane defined for the problem, the following traffic data for the time period T hours are required to execute SNAP 1.0:

- Average Lane Speed, S_j, in kilometres per hour
- Number of Vehicles of Each Type, N_{ij}, in vehicles per hourly time period T.

Subscript i denotes a vehicle type and subscript j denotes a lane.

2.3.1 Noise Emission Levels

SNAP 1.0 estimates vehicle noise emissions in terms of the reference energy mean emission level $(\overline{L}_0)_E$ as defined in Reference 1. This level is defined at a reference distance, D_0, of 15m from a traffic lane. SNAP 1.0 estimates $(\overline{L}_0)_E$ as a function of vehicle speed, S,in kilometres per hour, using the basic relationship:

$$(\overline{L}_0)_E = A + B\log(S) \qquad (2\text{-}1)$$

The coefficients A and B in Equation (2-1) depend upon the vehicle type (1), (3).

SNAP 1.0 allows the user to specify a maximum of four vehicle types for each lane. The first three vehicle types are defined by SNAP 1.0 using stored values for the coefficients A and B. The user may additionally specify an optional vehicle type by defining values for the coefficients A and B. The definition of these coefficients requires a rather extensive experimental data base (3) and must be defined for the reference distance of 15m.

SNAP 1.0 defines vehicle types as follows:

Type 1 Vehicles - Passenger Cars and Light Trucks:

All vehicles with two axles and four wheels designed primarily for transportation of nine or fewer passengers and for transportation of cargo. Generally, the vehicle weight is less than 4536 kg*.

Type 2 Vehicles - Medium Trucks:

All vehicles having two axles and six wheels designed for transportation of cargo. Generally, the vehicle weight is greater than 4536 kg* but less than 11,800 kg*.

Type 3 Vehicles - Heavy Trucks:

All vehicles having three or more axles and designed for the transportation of cargo. Generally, the vehicle weight is greater than 11,800 kg*.

Type 4 Vehicles - User-Defined Vehicle:

Any sound level specification in the form of Equation (2-1) that applies to constant-speed cruise conditions between 50 to 100 km/h.

The data base upon which Equation (2-1) is defined for Type 1 through 3 restricts traffic flow noise simulation to cruise conditions at speeds between 50 km/h and 100 km/h. If the user defines a lane speed outside this range, warning messages are printed as described in Section 4.

Figure 2-2 presents a plot of $(\overline{L}_0)_E$ versus speed for the three vehicle types defined by SNAP 1.0.

*kg denotes kilograms force or Newtons.

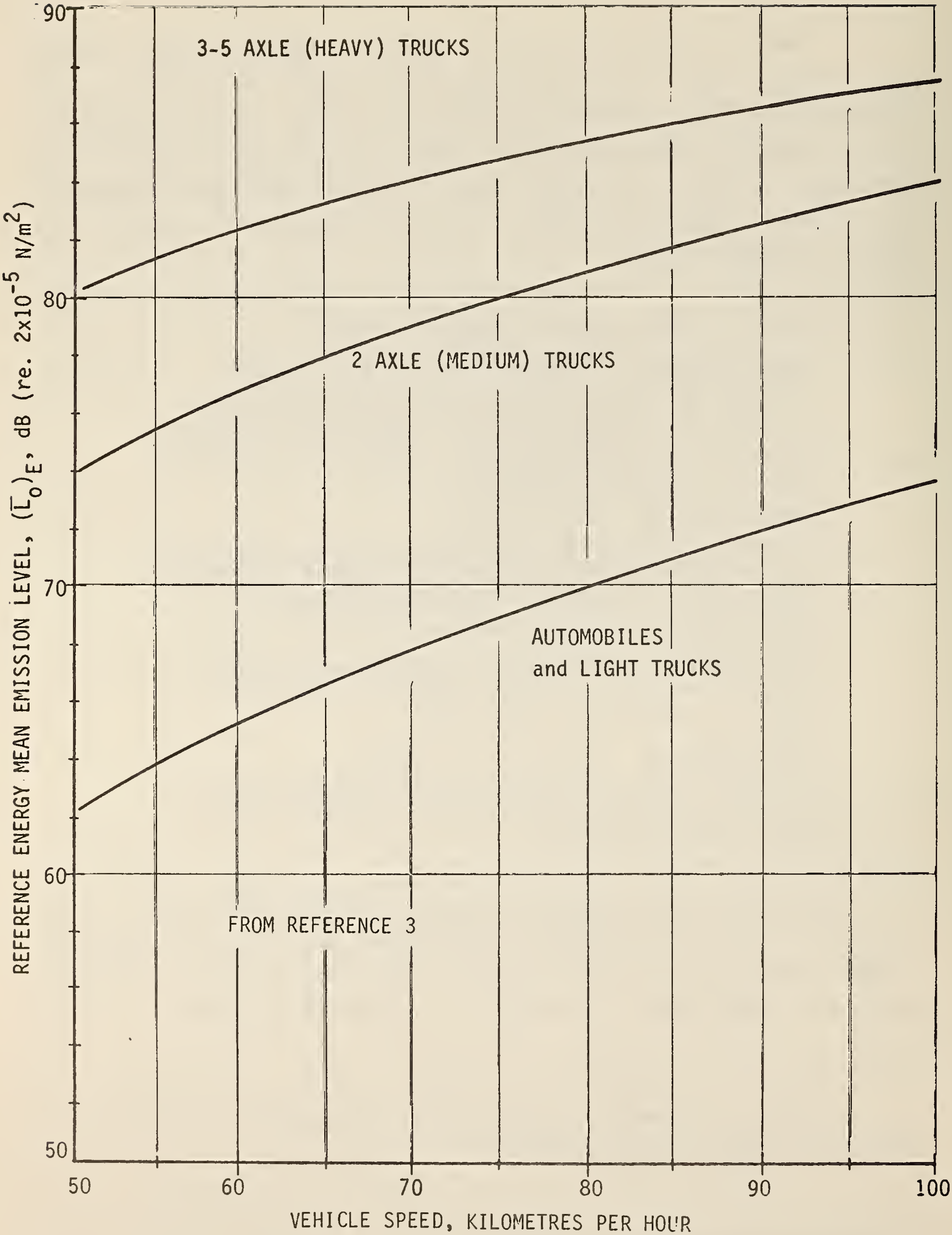


FIGURE 2-2. ENERGY MEAN EMISSION LEVELS AS A FUNCTION OF VEHICLE SPEED

2.3.2 Source Heights

For each vehicle type, the user must specify a source height defining the "acoustic center" of the vehicle relative to the lane elevation. The following values for vehicle source heights are recommended:

Vehicle Type	Vehicle Source Height, metres
Passenger Cars & Light Trucks	0.0
Medium Trucks	0.7
Heavy Trucks	2.44
Other Vehicles	As Judged by User

These values are used for each vehicle type on each lane in the barrier attenuation calculations.

For each traffic lane, the user specifies the average speed, S, in kilometres per hour and the number of each vehicle type comprising the traffic flow on the lane. The vehicle count must correspond to the time period, T, defining the problem.

2.4 Sound Level Adjustments

The reference energy mean emission levels defined by SNAP 1.0 are based upon vehicles operating under cruise conditions on flat terrain. To improve the flexibility of the SNAP 1.0 model, the user may specify constant sound level adjustments for any vehicle type on any traffic lane. These adjustments may be used, for example, to include the effects of grade in the traffic noise predictions. SNAP 1.0 uses the sound level adjustments by adding the constant to the vehicle reference energy mean emission level for each vehicle type on each traffic lane. The sound level adjustments may be positive or negative depending upon the nature of the effect that the user is simulating.

To provide the user with guidance, sound level adjustments for grade effects are presented. These adjustments are not based upon an extensive experimental data base. References 4 and 5 indicate procedures that can be used. The two procedures give different results but both are based upon a positive adjustment only for heavy trucks moving on an uphill grade. The user should remember that for grades exceeding 7 percent, trucks cannot operate at a constant speed.

Based upon the results of Reference 4, a constant sound level adjustment, expressed in dB, is applied for heavy trucks moving up a grade. The recommended adjustments are:

Gradient %	Adjustment, dB
Less than 2	0
3 to 4	+2
5 to 6	+3
Greater than 7	+5

Based upon the results of Reference 5, sound level adjustments for heavy trucks moving up a grade are:

$$\text{Adjustment} = 7.28 - 3.3\log(S) + G, \text{ dB} \qquad (2\text{-}2)$$

where S is the heavy truck speed, km/h
G is the grade in percent (less than 7)

The result of Equation (2-2) is presented in Figure 2-3. The user will note that the grade adjustments estimated using Equation (2-2) are larger than the adjustments indicated by Reference 4. It is recommended that the Reference 4 grade adjustments be used until future research can provide better data (1).

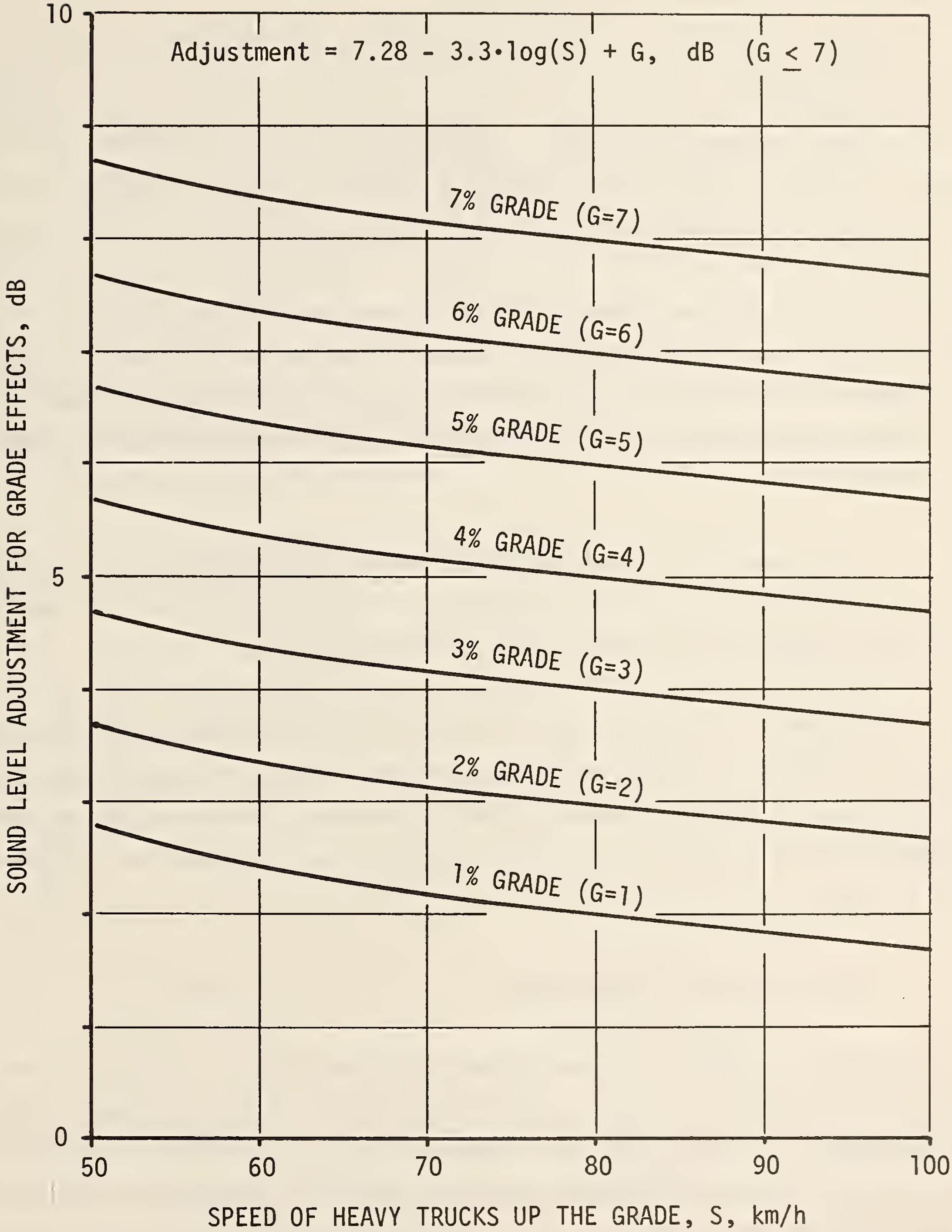


FIGURE 2-3. HEAVY TRUCK SOUND LEVEL ADJUSTMENT FOR GRADES (Reference 5)

2.5 Barrier Attenuation

SNAP 1.0 defines a barrier by type and geometric alignment. The user may specify a barrier as either a "thin screen" or as a "berm". A thin screen barrier simulates a structural wall. A "berm" simulates a mound of earth. SNAP 1.0 considers a barrier to be of constant elevation with noise diffracting over the top edge of the barrier. Diffraction around the ends of the barrier is ignored. The barrier diffraction model used by SNAP 1.0 assumes that a lane is parallel to the top edge of the barrier. Additionally, a berm is assumed to provide 3 dB more attenuation than a thin screen for a given source-barrier-receiver geometry. Thin screens are limited to a maximum of 20 dB attenuation and berms to 23 db attenuation.

The geometric specification of a barrier for SNAP 1.0 requires the (x,y) coordinates of each end point of the barrier and the constant elevation (z-coordinate) of the top edge of the barrier.

The SNAP 1.0 user does not have to be concerned with the location of a lane relative to the barrier other than the requirement for parallel line segments. SNAP 1.0 will correctly resolve the geometry to determine the segments of each lane that are shielded or unshielded by the barrier.

2.6 Excess Distance Attenuation

Since the SNAP 1.0 model does not recognize a ground plane as such, the user must specify a value for the site excess distance attenuation parameter, α, for each lane relative to the receiver. The theory associated with this distance attenuation model is described in Reference 1. The specification of "alpha", α, for each lane applies only to subsegments of the lane that are unshielded by the barrier. The user must exercise engineering judgement when specifying a value for α. For guidance, the following relation between α and a distance attenuation rate, n, in dB per distance doubling is presented:

$$n = 3(1+\alpha), \text{ dB/DD} \qquad (2\text{-}3)$$

The user should remember the following in formulating input data:

- $\alpha = -1.0$ $\quad n = 0$ dB/DD (Zero Distance Attenuation)
- $\alpha = -0.5$ $\quad n = 1.5$ dB/DD
- $\alpha = 0.0$ $\quad n = 3.0$ dB/DD (Classical Line Source)
- $\alpha = 0.5$ $\quad n = 4.5$ dB/DD
- $\alpha = 1.0$ $\quad n = 6.0$ dB/DD (Classical Point Source)

SNAP 1.0 utilizes numerical integration to evaluate the various functions dependent upon the parameter α (See Appendix A). Hence, the user may specify α as any value greater than -1.0. If the user does not specify a value for α for a lane, the value of α remains at the last specified value used by SNAP 1.0.

2.7 Unlimited Number of Receiver Locations

SNAP 1.0 defines a receiver location by a point with (x,y,z) coordinates. No adjustments to the receiver location are conducted internally to the program. The only restrictions on receiver location are that a receiver may not be closer than 15 metres from a lane segment or 0.5 metre from the top edge of a barrier. Violation of these restrictions will terminate execution of the program. The number of receiver locations is unlimited.

2.8 Tabulated Output

SNAP 1.0 predicts the L_{eq} metric at the receiver contributed by each vehicle type defined for each lane. The L_{eq} contribution at the receiver is subtotaled for vehicle types and for lanes. Of course, the total L_{eq} estimate is presented. For each vehicle type on each lane, the L_{10} sound level metric is estimated from the L_{eq} value as described in Appendix A.3. The L_{10} metric is summed over vehicle types and lanes in a manner similar to the L_{eq} metric. These results are presented in the tabulated

format of Figure 2-4. In Figure 2-4, the notation "(NO BARRIER ATTENUATION)" denotes that the results are for a site without a barrier.

If the user defines a barrier, SNAP 1.0 automatically predicts two additional tabulations similar to Figure 2-4 for receiver sound levels with barrier attenuation and the barrier field insertion loss.

As an output option, the user may direct SNAP 1.0 to print five additional tables that further quantify the barrier noise attenuation performance. For the maximum limit of 12 lanes, the tabulations generated by SNAP 1.0 fit directly on a page without photographic reduction.

The specific form and description of the output data provided by SNAP 1.0 are presented in Section 6.

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 1

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(NO BARRIER ATTENUATION)

SITE-01:RUN-04:FHWA-RD-76-54:STATION 1

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-6.80	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	65.28	0.0	70.97		72.01
		L10	69.11	0.0	71.58		73.53
2	0.50	LEQ	63.91	0.0	69.60		70.64
		L10	67.61	0.0	71.25		72.81
3	0.50	LEQ	62.77	0.0	68.46		69.50
		L10	66.36	0.0	70.79		72.12
4	0.50	LEQ	61.80	0.0	67.49		68.53
		L10	65.27	0.0	70.27		71.47
5	0.50	LEQ	60.96	0.0	66.64		67.68
		L10	64.32	0.0	69.75		70.85
6	0.50	LEQ	59.33	0.0	63.87		65.18
		L10	62.48	0.0	66.95		68.28
7	0.50	LEQ	58.73	0.0	63.28		64.59
		L10	61.81	0.0	66.55		67.81
8	0.50	LEQ	58.19	0.0	62.74		64.04
		L10	61.20	0.0	66.16		67.36
9	0.50	LEQ	57.69	0.0	62.24		63.54
		L10	60.63	0.0	65.78		66.94
10	0.50	LEQ	57.22	0.0	61.77		63.08
		L10	60.10	0.0	65.41		66.53
VEHICLE TOTALS		LEQ	71.42	0.0	76.86		77.95
		L10	74.93	0.0	79.07		80.48

L_{eq} Contribution From Heavy Trucks on Lane 3

Total L_{eq} Contribution from Lane 5 for All Vehicles

Total L_{eq} Contribution from Automobiles on All Lanes

Total Receiver L_{eq}

FIGURE 2-4. TABULAR FORMAT OF SNAP 1.0 SOUND LEVEL ESTIMATES

3.0 NOTES ON FORMULATING PROBLEMS

The FHWA Level 1 highway traffic noise prediction program, SNAP 1.0, is designed to consider rather simple site configurations comprising lanes, receivers and a single barrier. If a barrier is defined, all lanes must be parallel to the barrier. All lanes and the barrier are described geometrically by straight line segments. Each straight line segment is at a constant elevation. This section presents notes on formulating problems for solution using SNAP 1.0. If the user decides that SNAP 1.0 cannot accurately define a problem based upon its inherent geometric restrictions, the user may consider the more general FHWA Level 2 program (2).

Basically, SNAP 1.0 applies to sites that are essentially flat. The applicability of the SNAP 1.0 model to a specific problem can only be decided based upon the relative alignment of the lanes, the barrier, and the receivers.

3.1 Formulating Geometry

The formulation of site geometry for SNAP 1.0 requires the user to define the location of points and line segments in a (x,y,z) coordinate space. The x-y coordinates define the location of a point in the horizontal plane. The z coordinate defines the vertical location of the point. Receiver locations are defined by the points (x,y,z) at which the user desires the sound level estimates.

Lanes and the top edge of a barrier are defined by straight line segments. A straight line segment is defined for SNAP 1.0 by specifying the x-y coordinates of each end point and a z coordinate (elevation). Hence, SNAP 1.0 considers all lanes and a barrier* to be parallel to the horizontal plane z = 0.0. Any coordinate value (x, y or z) may be specified as positive or negative as the user desires.

*Barrier location implies the top edge of the barrier

SNAP 1.0 considers only finite length line segments. Hence, if the user desires to define an "infinite" coordinate, he must specify a "large" value for the coordinate. As described in Section 5, SNAP 1.0 accepts input data for coordinate definition up to a maximum of 8 significant digits. The user should not find this restriction significant but should remember that the definition of "large" or "small" is relative to the maximum distance of a receiver from a lane for a given problem. Generally, the user should limit receiver locations to within 300 metres of any traffic lane. SNAP 1.0 will properly define the relative locations of the lanes, the barrier and the receiver without the user considering the conversion of absolute (i.e., map) coordinates to local (site) coordinates.

The user must always remember that a complex site geometry may be amenable to solution using SNAP 1.0 within the restrictions placed on the geometric problem. This is accomplished by dividing the complete problem into subproblems that can be accurately considered by SNAP 1.0. Such a subdivision is required only if the site deviates significantly from a "flat" configuration* or if the user requires accurate barrier attenuation calculations considering all lanes.

3.2 Roadway Configurations

SNAP 1.0 considers multi-lane roadway configurations. Each lane is defined by its location (a straight line segment of constant elevation) and by the traffic flow on the lane. Accurate modeling of the site geometry for the purposes of traffic noise estimates using SNAP 1.0 essentially requires a site where each lane may be located at a constant elevation for all receivers. Concerning this point, engineering judgement of the user is required. Generally, the user may ignore lanes at a distance greater than 300 metres from any receiver.

*A "flat" configuration means that each lane appears to each receiver as a constant elevation line source.

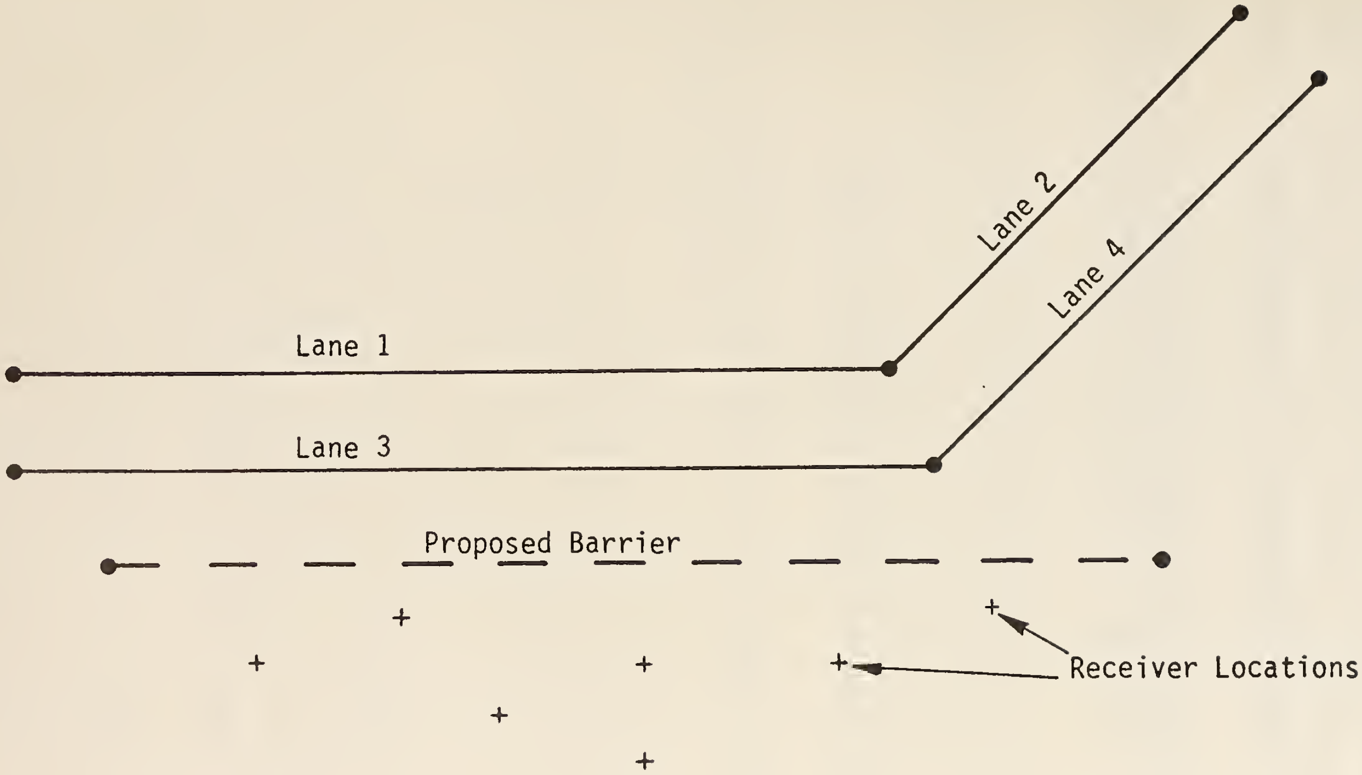
After deciding the applicability of site "flatness" , the user must decide whether or not barrier attenuation is required. If barrier attenuation calculations are not required, the user may define an arbitrary orientation, in the horizontal plane, for the roadway segments. If the user requires barrier attenuation calculations, all lane segments must be specified parallel to the top edge of the barrier.

3.2.1 Curved Alignments - No Barrier

For curved roadway alignments and no barrier attenuation, the user must specify the criterion for parallelism (See Section 5.1) as the maximum relative angular difference between any lane defined for the problem. By specifying the criterion as "90°", the user will allow any relative alignment of lanes. Curved roadway alignments must be specified using straight line segments with each segment at a specified elevation. Intersecting roadways or overpasses may be simulated if the user recognizes that SNAP 1.0 considers only freely flowing traffic and does not consider horizontal surfaces, i.e., potential shielding realized for an elevated roadway.

3.2.2 Curved Alignments - With Barrier

For curved roadway alignments with barrier attenuation, the user must exercise judgement in formulating problems using SNAP 1.0. The user may or may not be able to evaluate barrier attenuation accurately for curved roadway alignments using SNAP 1.0. Figure 3-1 illustrates the concepts involved for the user to decide the applicability of SNAP 1.0 to calculate highway traffic noise abatement for curved alignments with barrier attenuation. In any event, to evaluate receiver sound levels accurately, the user must conduct multiple executions of SNAP 1.0 and combine results external to the program execution. For complex site geometry, the user may decide to use the FHWA Level 2 program.



SNAP 1.0 Correctly Analyzes Site Without Barrier

SNAP 1.0 Correctly Analyzes Site With Barrier for Lanes 1 & 3

SNAP 1.0 Cannot Estimate Barrier Attenuation for Lanes 2 & 4

FIGURE 3-1. CONCEPTS REQUIRED TO EXECUTE SNAP 1.0 FOR COMPLEX SITES

3.3 Traffic Flow Conditions

In formulating traffic flow conditions for input to SNAP 1.0, the user must recognize that all traffic data for all lanes must correspond to the time period, T, specified for the problem (see Sections 5.1 and 5.5). The user may specify 24-hour data, hourly data, half-hourly data, etc., as desired. The vehicle count, by type and lane, and the travel speed, by lane, must be consistent with the time period specified. The predicted sound level metrics L_{eq} and L_{10} apply to the specified time period.

If the user specifies vehicle sound level adjustments to simulate grade effects, the traffic flow must be defined for the uphill direction and the downhill direction.

4.0 ERROR MESSAGES

The FHWA Level 1 highway traffic noise prediction program prints error messages to advise the user of violations of basic assumptions upon which the program is based. Two types of error messages are printed: warnings and fatal errors. Warnings do not halt execution of SNAP 1.0. Fatal errors halt execution.

4.1 Error Messages Occurring During Input

As SNAP 1.0 reads input data, audits of the data are performed to ensure that certain criteria are not exceeded.

Exceeding the speed range limits for vehicle cruise conditions (see Section 2.3.1) results in the following error messages as appropriate:

"LANE XX SPEED XXX IS LESS THAN 50 AND IS SET TO 50"
"LANE XX SPEED XXX IS GREATER THAN 100 AND IS SET TO 100".

These messages are warnings and the program execution continues with the adjustments as noted.

If the angular deviation of a lane from the specified criteria for parallelism is exceeded, SNAP 1.0 prints the following message:

"LANE XX IS NOT PARALLEL".

This message signals a fatal error. Execution of SNAP 1.0 is terminated. The user should check the geometric (x,y) coordinates used to specify the lane and/or increase the criterion for parallelism, as necessary. The user may refer to Section 2.2 and Figure 2-1 for the discussion of criteria specification.

4.2 Error Messages Occurring During Execution

During execution, SNAP 1.0 audits calculations to ensure that the user has not defined a receiver closer than 15.0 metres to a lane or closer than 0.5 metre to a barrier. If either of these situations occur, the following messages are printed:

"LANE XX IS TOO CLOSE"
"OBSERVER TOO CLOSE TO BARRIER"

These error messages are fatal. Execution of SNAP 1.0 is terminated if either message is printed. The user should adjust the observer location as appropriate.

5.0 INPUT DATA REQUIREMENTS

The input data requirements to execute SNAP 1.0 are simple; however, the format for input data is rigid. Except as noted below, all data must be defined in the indicated sequence for proper execution of SNAP 1.0. The input data are defined in data blocks. Each data block comprises several cards, as described below. The data blocks, in sequence, are:

(1) Initialization and Option Parameters
(2) Barrier Geometry
(3) Lane Geometry, Traffic Flow, and Sound Level Adjustment
(4) Receiver Location and Alpha Definition.

For each definition of data for blocks (1) through (3) above, the user may define as many receiver locations as desired before execution of the program is terminated. The data block sequence is illustrated in Figure 5-1.

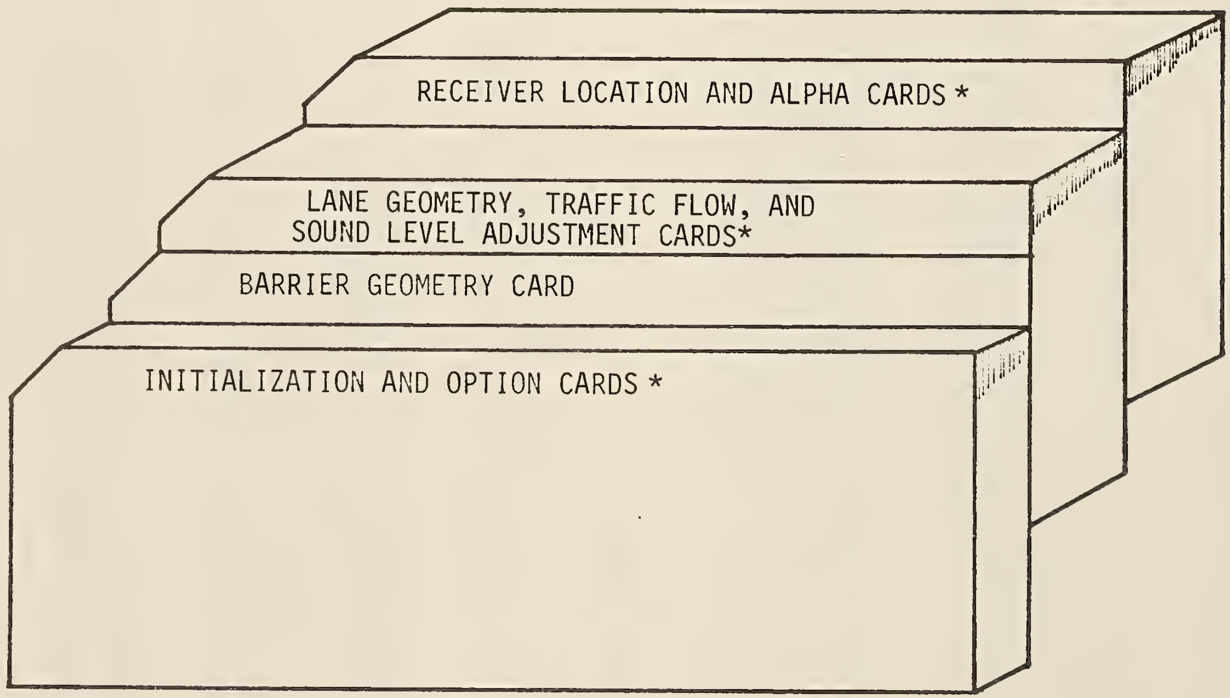
5.1 Input Data Format

The FHWA Level 1 prediction program accepts input data from a card reader. Three types of input data format are allowed by the code:

- <u>Integer Format</u> - A fixed point number written without a decimal point. All integers must be right-justified within the allotted field of the input card.
- <u>Real Constant</u> - A floating point number written with a decimal point. Normally, the real number may be situated anywhere within its allotted field on the card.
- <u>Alphanumeric</u> - Any combination of alphabetic and numeric characters. Alphanumeric data may be located anywhere within the allotted field on a card.

5.2 Initialization and Option Parameters

SNAP 1.0 uses initialization and option parameters to define the general characteristics of the problem the user desires to solve.



*Mandatory for execution

FIGURE 5-1. INPUT DATA BLOCK SEQUENCE: SNAP 1.0

The sequence and format of the initialization parameters required for SNAP 1.0 are indicated in Figure 5-2.

The first card defines the following parameters in the indicated format:

T, the time in hours for which the L_{eq} and L_{10} values are to be estimated.

EPS, the type of barrier to be used for noise attenuation

EPS = 0.0 denotes a thin screen
EPS = 1.0 denotes a berm.

THETA, the maximum allowable angle in degrees to evaluate parallelism of line segments in the horizontal (x,y) plane. The limits on THETA are:

THETA = 0° denotes perfectly parallel segments
THETA = 90° denotes arbitrary segment orientation (use only if barrier attenuation is not required).

The second card defines the user option for printing sound level estimates. The following options rigidly apply:

NOP = 0 Directs SNAP 1.0 to print eight tables describing the traffic noise levels at each receiver. This option should be elected only if the user defines a barrier. Detailed discussion of these tables is presented in Section 6.

NOP = 1 Directs SNAP 1.0 to print either one table or three tables describing the traffic noise levels at each receiver. If the user does not define a barrier (IBAR = 1), one table describing the receiver sound levels will be printed (See Figure 2-4). If the user defines a barrier (IBAR = 2), SNAP 1.0 will print three tables describing the receiver sound levels without the barrier, receiver sound levels with the barrier, and the barrier field insertion loss.

The third card defines the types of vehicles required to define the problem. Generally, the user will define NI = 3 indicating that the traffic flows may comprise automobiles, medium trucks, and heavy trucks. The following usage applies:

DATA BLOCK 1: INITIALIZATION AND OPTION CARDS

- CARD 1: INITIALIZATION PARAMETERS

COLUMN (FORMAT)	1(F6.0)	7(F6.0)	13(F6.0)
NAME	T	EPS	THETA

- CARD 2: OPTION CARD FOR TABLE PRINTING

COLUMN (FORMAT)	2(I2)*
NAME	NOP

- CARD 3: NUMBER OF VEHICLE TYPES

COLUMN (FORMAT)	2(I2)
NAME	NI

- CARD 4: VEHICLE SOURCE HEIGHT SPECIFICATION

COLUMN (FORMAT)	1(F6.0)	7(F6.0)	13(F6.0)	19(F6.0)
NAME	H(1)	H(2)	H(3)	H(4)
Notes	Autos	Med.Trk.	Hvy.Trk.	Other Veh.

- CARD 4.1: OPTIONAL VEHICLE NOISE EMISSION CARD (ONLY IF NI=4)

COLUMN (FORMAT)	1(F6.0)	7(F6.0)
NAME	A(4)	B(4)

- CARD 5: BARRIER OPTION CARD

COLUMN (FORMAT)	2(I2)
NAME	IBAR

- CARD 6: GEOMETRY INITIALIZATION CARD

COLUMN (FORMAT)	2(I2)
NAME	NJ

* 2(I2) denotes an integer format right justified in the indicated column.

FIGURE 5-2: INPUT SEQUENCE AND FORMAT: INITIALIZATION AND OPTION CARDS

NI = 1, consider only automobiles in the sound level estimate

NI = 2, consider automobiles and medium trucks in the sound level estimate

NI = 3, consider automobiles, medium trucks, and heavy trucks in the sound level estimate

NI = 4, consider automobiles, medium trucks, heavy trucks and a user-defined "other vehicle" in the sound level estimate.

The fourth card defines the vehicle source heights, in metres, needed to define the elevation of the vehicle "acoustic center" relative to each lane elevation. A source height must be specified in the indicated field on the card for the number (NI) of vehicle types specified on the third card.

If the user specifies NI = 4, an optional vehicle noise emission card must be included to define the vehicle noise emission as a function of speed (See Section 2.3.1). Two constants are required. The constant A is the speed-independent term. The constant B is the coefficient on the log-speed term. If NI = 3, this card should be deleted.

The fifth card required for the initialization parameters specifies the user option to define a barrier. If IBAR = 1, no barrier is to be defined and SNAP 1.0 will calculate only traffic noise estimates for the defined lanes and receivers. If IBAR = 2, a barrier is to be defined and SNAP 1.0 will calculate the receiver sound levels without the barrier, with the barrier, and the barrier field insertion loss (see card 2).

The sixth card defines the total number of cards to be read to define the locations of the barrier and the lanes. For example, six lanes and a barrier requires NJ = 7. The definition of seven lanes with no barrier requires NJ = 7. The maximum value of NJ is 13 if a barrier is defined and 12 if a barrier is not defined.

5.3 Barrier Geometry

One card is required to define the barrier location for SNAP 1.0. If IBAR = 1, the barrier geometry card is deleted from the data set. If IBAR = 2, the barrier geometry card must be included in the data set. The format and sequence of the coordinate input values are indicated in Figure 5-3.

5.4 Lane Geometry, Traffic Flow Definition and Sound Level Adjustments

Three cards are required for each lane to define the lane geometry, the traffic flow conditions, and the vehicle sound level adjustments. The input data sequence is a geometry card, a traffic flow card, and a sound level adjustment card for each lane. This sequence is indicated in Figure 5-4.

The first lane card defines the coordinates describing the lane geometry. The second lane card defines the operating speed and the vehicle count by vehicle type for the lane. The user must define the number of each vehicle type (NI as defined in the initialization parameters) present on the lane. If a vehicle type is not present, its count must be specified as zero. The travel speed and the vehicle count must correspond to the time period, T, defined by the initialization parameter. The third lane card defines the constant sound level adjustments for each vehicle type on the lane.

The lane cards are repeated until all lanes (specified by NJ) are defined.

5.5 Receiver Location and Alpha Definition

The definition of a receiver location requires two cards. The first card is an alphanumeric title card. The second card defines the receiver location (x,y,z coordinates) and the values of the "Alpha" parameter ( ) for each lane relative to the receiver. The input data format is defined in Figure 5-5.

• CARD 6.1 BARRIER GEOMETRY CARD (ONLY IF IBAR=2)

COLUMN (FORMAT)	1(F10.0)	11(F10.0)	21(F10.0)	31(F10.0)	41(F10.0)
NAME	XR1(1,1)	XR1(2,1)	XR2(1,1)	XR2(2,1)	XR2(3,1)
Notes:	X_1	Y_1	X_2	Y_2	Z_2

XR1(1,1) x-coordinate of end point "1" of barrier

XR1(2,1) y-coordinate of end point "1" of barrier

XR2(1,1) x-coordinate of end point "2" of barrier

XR2(2,1) y-coordinate of end point "2" of barrier

XR2(3,1) z-coordinate (elevation) of barrier

PROGRAM DEFINES XR1(3,1) = XR2(3,1)

FIGURE 5-3. BARRIER GEOMETRY CARD

THREE CARDS PER LANE. MAXIMUM OF 12 LANES

- CARD 7.J COORDINATE CARD FOR LANE 1

COLUMN (FORMAT)	1(F10.0)	11(F10.0)	21(F10.0)	31(F10.0)	41(F10.0)
NAME*	XR1(1,J)	XR1(2,J)	XR2(1,J)	XR2(2,J)	XR2(3,J)
Notes	X_1	Y_1	X_2	Y_2	Z_2

- CARD 7.J+1 TRAFFIC FLOW CARD FOR LANE J

COLUMN (FORMAT)	1(F6.0)	12(I6)	18(I6)	24(I6)	30(I6)
NAME	S(J)	N(1,J)	N(2,J)	N(3,J)	N(4,J)

CARD 7.J+2 VEHICLE NOISE SOURCE ADJUSTMENT

COLUMN (FORMAT)	1(F6.0)	7(F6.0)	13(F6.0)	19(F6.0)
NAME	AA(1,J)	AA(2,J)	AA(3,J)	AA(4,J)

S(J) traffic speed for lane J for time T
N(1,J) number of automobiles on lane J for time T
N(2,J) number of medium trucks on lane J for time T
N(3,J) number of heavy trucks on lane J for time T
N(4,J) number of type 4 vehicles on lane J for time T
AA(I,J) is the constant sound level adjustment, in dB, for vehicle type I on lane J

NOTE: LANES ARE NUMBERED IN THE ORDER OF THE INPUT SEQUENCE.

* See Figure 5-3 for coordinate nomenclature.

FIGURE 5-4. LANE GEOMETRY, TRAFFIC FLOW AND SOUND LEVEL ADJUSTMENT

TWO CARDS PER RECEIVER, MAXIMUM NUMBER IS UNLIMITED

- CARD 8.K TITLE CARD FOR RECEIVER IDENTIFICATION

COLUMN (FORMAT)	1(10(A4))
NAME	USER SUPPLIED TITLE: 40 ALPHANUMERIC CHARACTERS

NOTE: IF TITLE CARD IS NOT INCLUDED FOR EACH RECEIVER EXECUTION IS HALTED.

- CARD 8.K+1 RECEIVER COORDINATES AND ALPHA CARDS

COLUMN (FORMAT)	1(F10.0)	11(F10.0)	21(F10.0)	31(12(F4.0))
NAME	XO(1)	XO(2)	XO(3)	ALPHA(J)

XO(1) x-coordinate of receiver

XO(2) y-coordinate of receiver

XO(3) z-coordinate of receiver

ALPHA(J) value of α for each lane relative to the receiver ALPHA(J) must be in the sequence 1, 2, 3, etc.

NOTE: LANES ARE NUMBERED IN THE ORDER OF THEIR INPUT SEQUENCE.

FIGURE 5-5. RECEIVER LOCATION AND ALPHA CARDS

The alphanumeric title is printed for each tabular output provided by SNAP 1.0 in the line above the location of the receiver coordinates (See Figure 2-4). The user may specify the title as desired.

Specification of a receiver and the values of each lane relative to a receiver completes the definition of a problem for SNAP 1.0. By including a sequence of title cards and receiver location/alpha cards, the user may repeat the sound level estimates for other receiver locations surrounding the roadway-barrier geometry defined for the data set. The number of receiver locations is limited only by the user's computing budget.

6.0 EXAMPLE PROBLEMS

This section presents three example problems illustrating the use of SNAP 1.0 to predict highway traffic noise emissions. The first example is a multi-lane roadway with a barrier and two receivers. The second example is a single "equivalent lane" with a finite barrier. The first example is compared to field measured values of L_{eq} and L_{10}. The second example problem illustrates the complete output tabular format used by SNAP 1.0. The third example problem illustrates the use of the vehicle sound level adjustments to simulate grade effects.

6.1 Example Problem 1: Comparison to Field Measurements

This example problem is a simulation of a field test site reported in Reference 6. The example simulates the data of SITE 01 (SR-7, Long Beach, CA) and the traffic flow data of RUN 04. The site is a straight, ten-lane roadway at a constant elevation with a median and a thin screen barrier 3.66 metres above the roadway elevation. In the terminology of Reference 6, the receivers are taken as Station 01 and the Reference Station. The measured sound levels at the site (6, page D-2) for the ten minute (0.167 hour) sample time are:

Receiver	L_{eq}	L_{10}	L_{50}
Ref. Station	75.9	78.8	74.1
Station 01	67.6	70.2	66.4

For the purposes of using SNAP 1.0, it is decided to uniformly distribute the traffic flow over the five near lanes and the five far lanes. The traffic mix is simulated using only the automobile (type 1) and the heavy truck (type 3) vehicles defined by SNAP 1.0. Since the experimental data comprised a ten minute (0.167 hour) sample of noise data and traffic flow, it is decided to simulate this sample time. Hence, the hourly traffic flow conditions defined for RUN 04 on page C-2 of Reference 6 are divided by 6 to obtain the conditions for the problem. The number of vehicle types on each lane are rounded to integers based upon the percentage of truck traffic indicated. Since the roadway is at a constant elevation, no vehicle sound level adjustments are required.

Since the site represents a straight infinite length roadway/barrier configuration, the end points of the lanes and the barrier are spaced symmetrically about the receiver locations. For convenience, the site (x,y,z) coordinate system is placed at the barrier with the ground plane placed at the roadway elevation. The site geometry is illustrated in Figure 6-1.

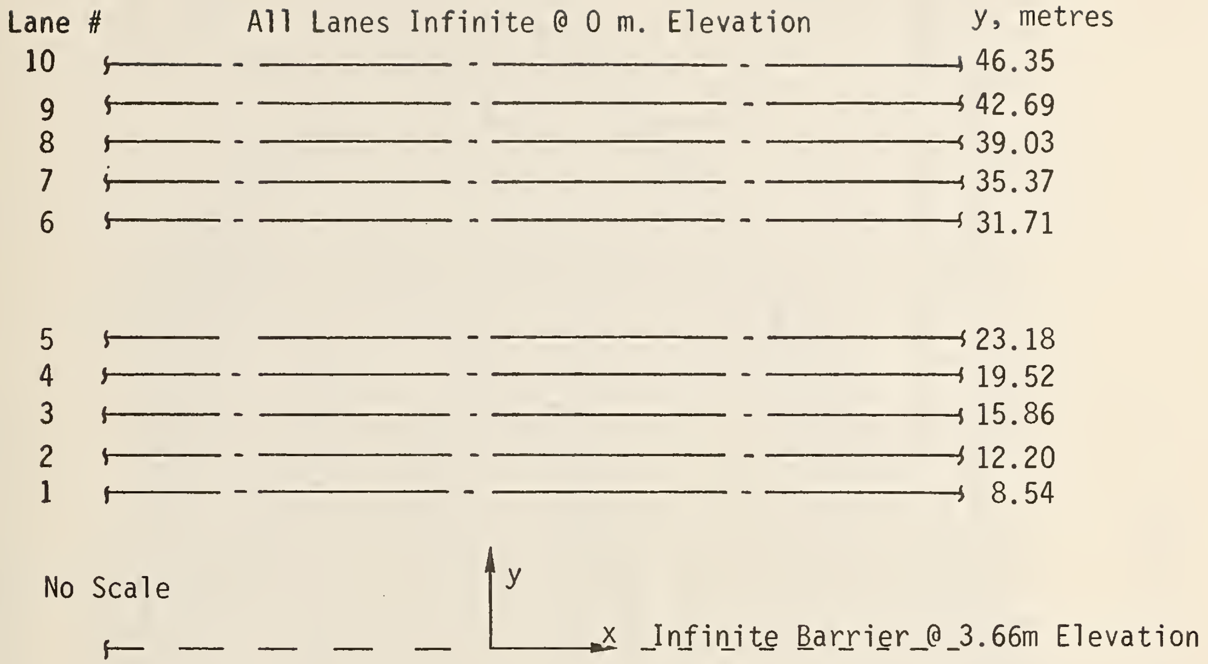
The input data defining the site for SNAP 1.0 execution are presented in Figure 6-2. It is decided that only the sound level estimates with and without the barrier and the barrier field insertion loss are desired (NOP = 1). Hence, SNAP 1.0 will compute and print six tabulations, three for each receiver.

Figure 6-3 presents the SNAP 1.0 tabulated traffic noise estimates for Station 01. Four tables are printed. The first table presents the input data and is printed once for each set of receivers. "TABLE 1" presents the sound level estimates of Station 01 for the site without the barrier, i.e., the "before barrier" configuration. "TABLE 2" presents the sound level estimates of Station 01 for the site with the barrier. "TABLE 3" presents the barrier field insertion loss estimates (TABLE 1 values less TABLE 2 values).

As indicated in TABLE 2 of Figure 6-3, the estimated receiver L_{eq} value is 70.38 dB* and the estimated receiver L_{10} value is 73.08 dB*. These estimates compare to the experimental values: L_{eq} = 67.6 dB and L_{10} = 70.2 dB.

Figure 6-4 presents the SNAP 1.0 tabulated traffic noise estimates for the Reference Station. The SNAP 1.0 estimates for the Reference Station are: L_{eq} = 76.38 dB and L_{10} = 79.46 dB. The TABLE 1 estimates from SNAP are used to compare with the experimental values since the reference station was located with a direct line-of-sight to the traffic.

*Two digits are shown for SNAP 1.0 calculations, quote to nearest 10th dB.



+ Station 01* (0, -6.8, 2.14) (α=0.5 all lanes)

+ Reference (0, -13.11, 2.14) (α=0.5 all lanes)

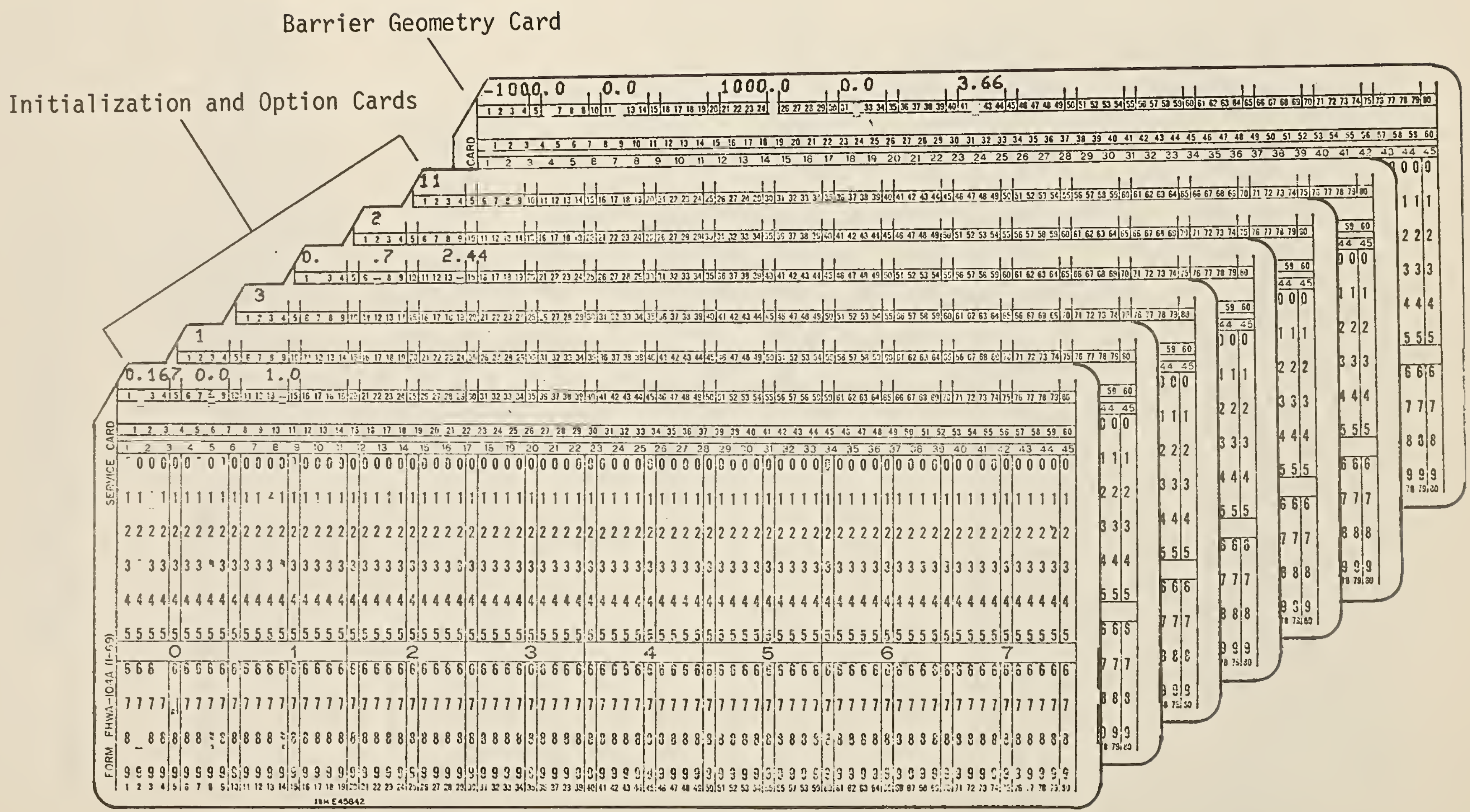
TRAFFIC FLOW DATA
Assumed Uniform for Near Lanes and Far Lanes

Near Lanes (#1 through 5): Speed 85 km/h
Vehicle Count Per Lane
Automobiles: 108 vehicles per 10 min. (648 per hour)
Heavy Trucks: 13 vehicles per 10 min. (78 per hour)

Far Lanes (#6 through 10): Speed 85 km/h
Vehicle Count Per Lane
Automobiles: 108 vehicles per 10 min. (648 per hour)
Heavy Trucks: 10 vehicles per 10 min. (60 per hour)

*Note: Station 01 location is reported in Reference 4 as (0, -6.10, 2.14). This location is 14.64 m from lane #1 and hence SNAP 1.0 will not execute problem. The location was changed to allow execution for this example. See Section 4.2.

FIGURE 6-1. EXAMPLE PROBLEM 1: SITE GEOMETRY AND TRAFFIC FLOW DATA

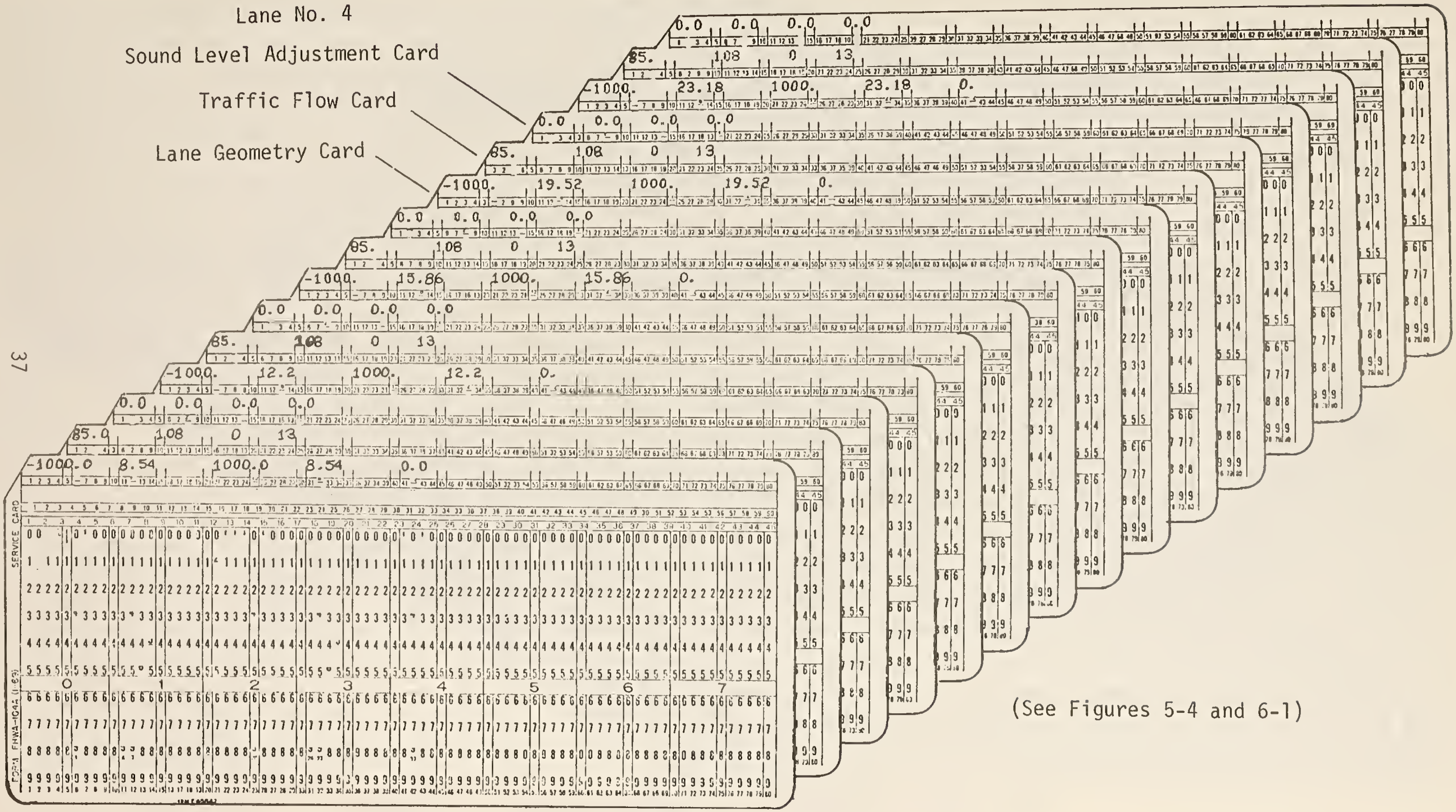


(See Figures 5-1 through 5-3 and Figure 6-1)

FIGURE 6-2. EXAMPLE PROBLEM 1: INPUT DATA

Lane Geometry, Traffic Flow, and Sound Level Adjustment Cards

(Lanes 1 through 5)

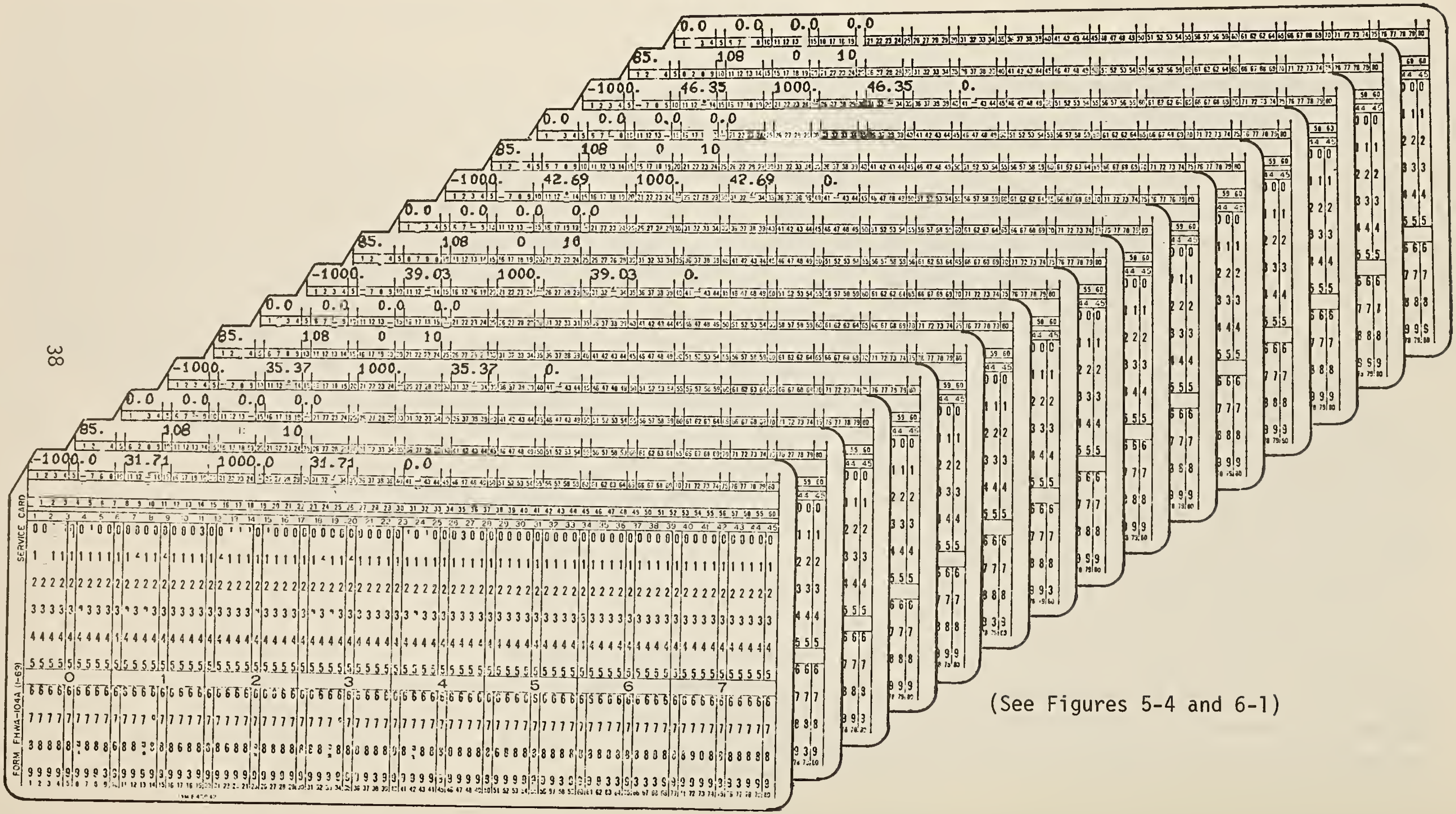


(See Figures 5-4 and 6-1)

FIGURE 6-2. EXAMPLE PROBLEM 1: INPUT DATA (Continued)

Lane Geometry, Traffic Flow, and Sound Level Adjustment Cards

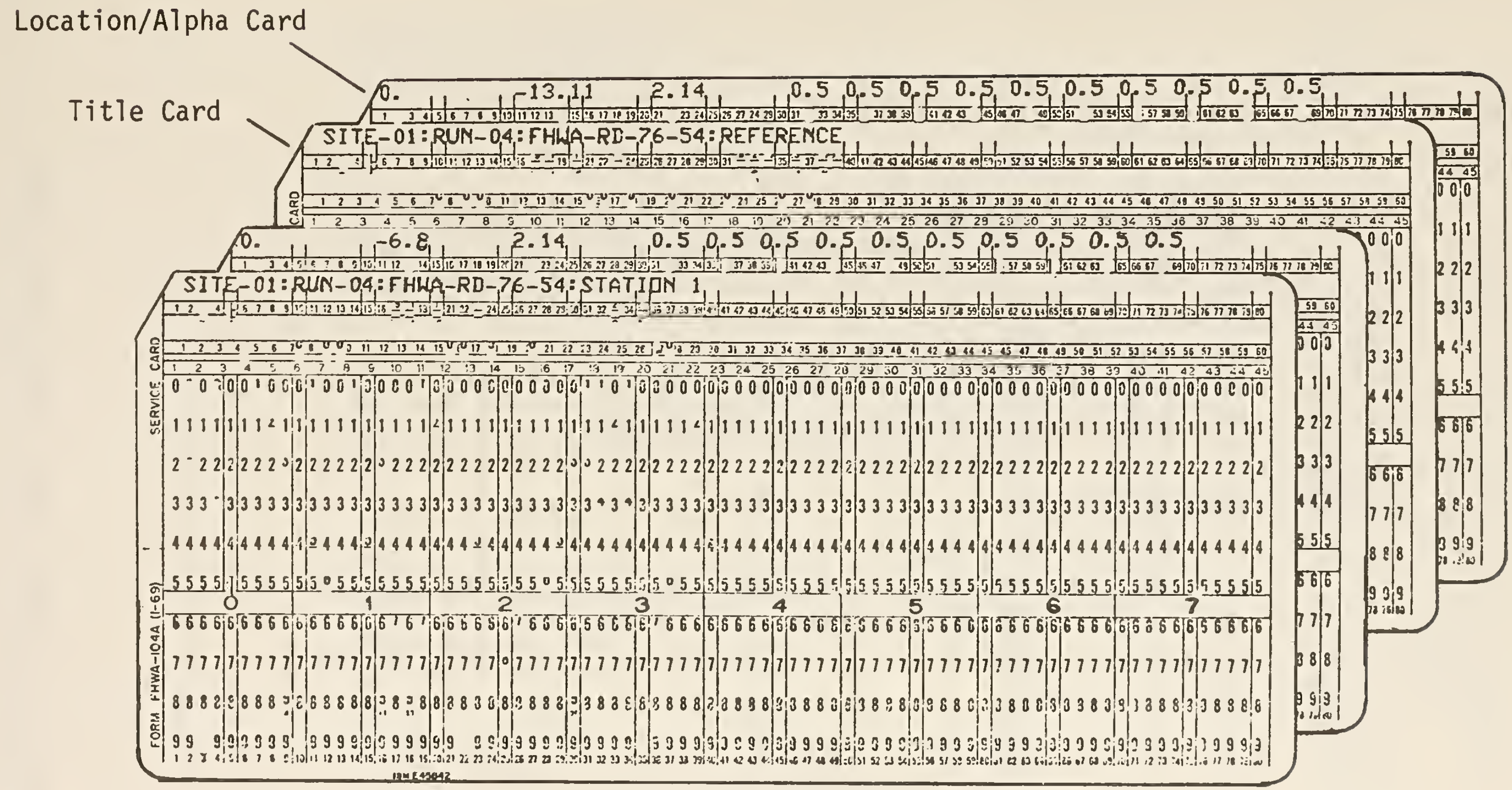
(Lanes 6 through 10)



(See Figures 5-4 and 6-1)

FIGURE 6-2. EXAMPLE PROBLEM 1: INPUT DATA (Continued)

Title and Receiver Location/Alpha Cards



(See Figures 5-5 and 6-1)

FIGURE 6-2. EXAMPLE PROBLEM 1: INPUT DATA (Concluded)

BASIC INPUT DATA

OPTION DATA

TIME INTERVAL FOR LEQ CALCULATIONS(HR)	=	0.17
EPSILON FOR BARRIER (0=THIN,1=BERM)	=	0.0
CRITERION FOR PARALLELISM(DEG)	=	1.00

SOURCE HEIGHT OF VEHICLES IN METRES

CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
0.0	0.70	2.44	

NOISE LEVEL-SPEED COEFFICIENTS (LO=A+B*LOG(S))

	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
A	-2.43	16.36	38.48	
B	38.05	33.91	24.56	

COORDINATES FOR END POINTS (METRES)

SEGMENT TYPE	X1	Y1	Z1	X2	Y2	Z2
BARRIER	-1000.00	0.0	3.66	1000.00	0.0	3.66
LANE # 1	-1000.00	8.54	0.0	1000.00	8.54	0.0
LANE # 2	-1000.00	12.20	0.0	1000.00	12.20	0.0
LANE # 3	-1000.00	15.86	0.0	1000.00	15.86	0.0
LANE # 4	-1000.00	19.52	0.0	1000.00	19.52	0.0
LANE # 5	-1000.00	23.18	0.0	1000.00	23.18	0.0
LANE # 6	-1000.00	31.71	0.0	1000.00	31.71	0.0
LANE # 7	-1000.00	35.37	0.0	1000.00	35.37	0.0
LANE # 8	-1000.00	39.03	0.0	1000.00	39.03	0.0
LANE # 9	-1000.00	42.69	0.0	1000.00	42.69	0.0
LANE # 10	-1000.00	46.35	0.0	1000.00	46.35	0.0

FIGURE 6-3. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR STATION 01

LANE #	SPEED (KM/H)	TRAFFIC VOLUME CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
1	85.0	108	0	13	
2	85.0	108	0	13	
3	85.0	108	0	13	
4	85.0	108	0	13	
5	85.0	108	0	13	
6	85.0	108	0	10	
7	85.0	108	0	10	
8	85.0	108	0	10	
9	85.0	108	0	10	
10	85.0	108	0	10	

SOUND-LEVEL ADJUSTMENT PARAMETER

LANE #	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
1	0.0	0.0	0.0	
2	0.0	0.0	0.0	
3	0.0	0.0	0.0	
4	0.0	0.0	0.0	
5	0.0	0.0	0.0	
6	0.0	0.0	0.0	
7	0.0	0.0	0.0	
8	0.0	0.0	0.0	
9	0.0	0.0	0.0	
10	0.0	0.0	0.0	

FIGURE 6-3. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR STATION 01 (Continued)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 1

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(NO BARRIER ATTENUATION)

SITE-01:RUN-04:FHWA-RD-76-54:STATION 1

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-6.80	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	65.28	0.0	70.97		72.01
		L10	69.11	0.0	71.58		73.53
2	0.50	LEQ	63.91	0.0	69.60		70.64
		L10	67.61	0.0	71.25		72.81
3	0.50	LEQ	62.77	0.0	68.46		69.50
		L10	66.36	0.0	70.79		72.12
4	0.50	LEQ	61.80	0.0	67.49		68.53
		L10	65.27	0.0	70.27		71.47
5	0.50	LEQ	60.96	0.0	66.64		67.68
		L10	64.32	0.0	69.75		70.85
6	0.50	LEQ	59.33	0.0	63.87		65.18
		L10	62.48	0.0	66.95		68.28
7	0.50	LEQ	58.73	0.0	63.28		64.59
		L10	61.81	0.0	66.55		67.81
8	0.50	LEQ	58.19	0.0	62.74		64.04
		L10	61.20	0.0	66.16		67.36
9	0.50	LEQ	57.69	0.0	62.24		63.54
		L10	60.63	0.0	65.78		66.94
10	0.50	LEQ	57.22	0.0	61.77		63.08
		L10	60.10	0.0	65.41		66.53
VEHICLE		LEQ	71.42	0.0	76.86		77.95
TOTALS		L10	74.93	0.0	79.07		80.48

FIGURE 6-3. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR STATION 01 (Continued)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 2

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(WITH BARRIER ATTENUATION)

SITE-01:RUN-04:FHWA-RD-76-54:STATION 1

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-6.80	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	53.23	0.0	62.40		62.90
		L10	56.54	0.0	64.25		64.93
2	0.50	LEQ	53.18	0.0	61.73		62.30
		L10	56.42	0.0	64.04		64.73
3	0.50	LEQ	52.99	0.0	61.10		61.73
		L10	56.16	0.0	63.72		64.42
4	0.50	LEQ	52.74	0.0	60.53		61.20
		L10	55.85	0.0	63.36		64.07
5	0.50	LEQ	52.48	0.0	60.02		60.72
		L10	55.52	0.0	62.99		63.71
6	0.50	LEQ	51.84	0.0	57.84		58.81
		L10	54.75	0.0	60.80		61.76
7	0.50	LEQ	51.57	0.0	57.45		58.45
		L10	54.44	0.0	60.51		61.47
8	0.50	LEQ	51.31	0.0	57.10		58.11
		L10	54.13	0.0	60.22		61.17
9	0.50	LEQ	51.07	0.0	56.76		57.80
		L10	53.84	0.0	59.94		60.89
10	0.50	LEQ	50.83	0.0	56.44		57.50
		L10	53.56	0.0	59.67		60.62
VEHICLE		LEQ	62.21	0.0	69.66		70.38
TOTALS		L10	65.25	0.0	72.30		73.08

FIGURE 6-3. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR STATION 01 (Continued)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 3

BARRIER FIELD INSERTION LOSS

SITE-01:RUN-04:FHWA-RD-76-54:STATION 1

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-6.80	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	12.06	0.0	8.57		9.11
		L10	12.57	0.0	7.32		8.60
2	0.50	LEQ	10.73	0.0	7.87		8.34
		L10	11.19	0.0	7.21		8.08
3	0.50	LEQ	9.78	0.0	7.36		7.77
		L10	10.19	0.0	7.07		7.71
4	0.50	LEQ	9.06	0.0	6.96		7.33
		L10	9.42	0.0	6.92		7.40
5	0.50	LEQ	8.48	0.0	6.63		6.96
		L10	8.81	0.0	6.76		7.14
6	0.50	LEQ	7.49	0.0	6.03		6.37
		L10	7.73	0.0	6.15		6.51
7	0.50	LEQ	7.16	0.0	5.83		6.14
		L10	7.38	0.0	6.05		6.34
8	0.50	LEQ	6.88	0.0	5.64		5.93
		L10	7.07	0.0	5.94		6.19
9	0.50	LEQ	6.62	0.0	5.48		5.75
		L10	6.79	0.0	5.84		6.04
10	0.50	LEQ	6.39	0.0	5.32		5.58
		L10	6.54	0.0	5.73		5.91
VEHICLE		LEQ	9.21	0.0	7.20		7.57
TOTALS		L10	9.68	0.0	6.76		7.40

FIGURE 6-3. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR STATION 01 (Concluded)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 1

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(NO BARRIER ATTENUATION)

SITE-01:RUN-04:FHWA-RD-76-54:REFERENCE

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-13.11	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	63.07	0.0	68.75		69.79
		L10	66.68	0.0	70.92		72.31
2	0.50	LEQ	62.06	0.0	67.74		68.78
		L10	65.56	0.0	70.42		71.65
3	0.50	LEQ	61.18	0.0	66.87		67.90
		L10	64.57	0.0	69.90		71.01
4	0.50	LEQ	60.41	0.0	66.09		67.13
		L10	63.70	0.0	69.38		70.42
5	0.50	LEQ	59.71	0.0	65.40		66.44
		L10	62.92	0.0	68.87		69.85
6	0.50	LEQ	58.34	0.0	62.83		64.19
		L10	61.36	0.0	66.27		67.48
7	0.50	LEQ	57.82	0.0	62.37		63.68
		L10	60.78	0.0	65.88		67.05
8	0.50	LEQ	57.35	0.0	61.89		63.20
		L10	60.24	0.0	65.51		66.64
9	0.50	LEQ	56.90	0.0	61.45		62.76
		L10	59.74	0.0	65.15		66.24
10	0.50	LEQ	56.49	0.0	61.03		62.34
		L10	59.27	0.0	64.79		65.87
VEHICLE		LEQ	69.89	0.0	75.28		76.38
TOTALS		L10	73.19	0.0	78.29		79.46

FIGURE 6-4. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR REFERENCE STATION

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 2

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(WITH BARRIER ATTENUATION)

SITE-01:RUN-04:FHWA-RD-76-54:REFERENCE

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-13.11	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	51.82	0.0	61.84		62.25
		L10	55.02	0.0	64.38		64.85
2	0.50	LEQ	52.16	0.0	61.52		61.99
		L10	55.28	0.0	64.29		64.80
3	0.50	LEQ	52.27	0.0	61.13		61.66
		L10	55.33	0.0	64.07		64.61
4	0.50	LEQ	52.26	0.0	60.74		61.32
		L10	55.26	0.0	63.80		64.37
5	0.50	LEQ	52.18	0.0	60.36		60.98
		L10	55.12	0.0	63.51		64.10
6	0.50	LEQ	51.87	0.0	58.42		59.28
		L10	54.70	0.0	61.52		62.34
7	0.50	LEQ	51.72	0.0	58.10		59.00
		L10	54.50	0.0	61.27		62.10
8	0.50	LEQ	51.55	0.0	57.80		58.73
		L10	54.30	0.0	61.02		61.86
9	0.50	LEQ	51.38	0.0	57.52		58.47
		L10	54.09	0.0	60.78		61.62
10	0.50	LEQ	51.22	0.0	57.25		58.22
		L10	53.89	0.0	60.54		61.39
VEHICLE		LEQ	61.86	0.0	69.80		70.45
TOTALS		L10	64.78	0.0	72.78		73.42

FIGURE 6-4. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR REFERENCE STATION (Continued)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 3

BARRIER FIELD INSERTION LOSS

SITE-01:RUN-04:FHWA-RD-76-54:REFERENCE

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-13.11	2.14

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	11.25	0.0	6.92		7.54
		L10	11.67	0.0	6.54		7.46
2	0.50	LEQ	9.90	0.0	6.23		6.79
		L10	10.27	0.0	6.13		6.84
3	0.50	LEQ	8.91	0.0	5.74		6.24
		L10	9.25	0.0	5.83		6.40
4	0.50	LEQ	8.15	0.0	5.35		5.82
		L10	8.45	0.0	5.58		6.05
5	0.50	LEQ	7.53	0.0	5.04		5.46
		L10	7.80	0.0	5.36		5.76
6	0.50	LEQ	6.46	0.0	4.47		4.91
		L10	6.66	0.0	4.75		5.14
7	0.50	LEQ	6.11	0.0	4.27		4.68
		L10	6.28	0.0	4.62		4.96
8	0.50	LEQ	5.80	0.0	4.09		4.48
		L10	5.95	0.0	4.49		4.78
9	0.50	LEQ	5.52	0.0	3.93		4.29
		L10	5.65	0.0	4.37		4.63
10	0.50	LEQ	5.27	0.0	3.78		4.12
		L10	5.38	0.0	4.26		4.48
VEHICLE		LEQ	8.03	0.0	5.48		5.93
TOTALS		L10	8.41	0.0	5.51		6.04

FIGURE 6-4. EXAMPLE PROBLEM 1: OUTPUT TABULATIONS FOR REFERENCE STATION (Concluded)

The experimental values quoted in Reference 4 are: L_{eq} = 75.9 and L_{10} = 78.8 dB. The differences between the SNAP 1.0 predictions and the experimental values of Reference 6 for SITE 01, RUN 4 are:

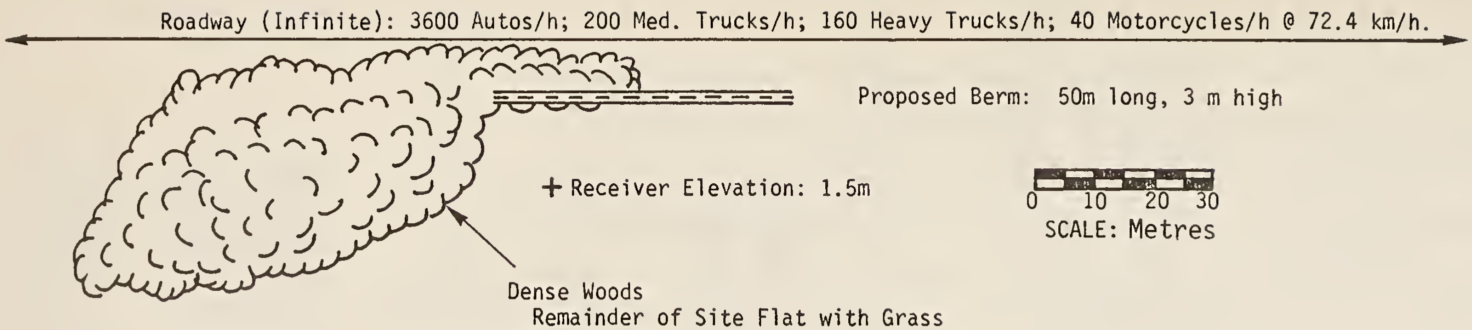
Receiver	$(L_{eq})SNAP - (L_{eq})Ref(6)$	$(L_{10})SNAP - (L_{10})Ref(6)$
Ref.Station (Table 1)	0.48	0.66
Station 01 (Table 2)	2.78	2.88

The usefulness of the results of Figures 6-3 and 6-4 is to evaluate the contribution to the receiver total sound level from each vehicle type on each lane. The numbers in the column labeled "LANE TOTALS" are the contribution of all vehicles on each lane to the total receiver sound level. The last two rows labeled "VEHICLE TOTALS" are the contributions to the receiver sound level (L_{eq} and L_{10}) for all lanes for the given vehicle type. The last two numbers in the "LANE TOTALS" column (intersection with "VEHICLE TOTALS" row) represent the predicted total receiver sound level metrics L_{eq} and L_{10}.

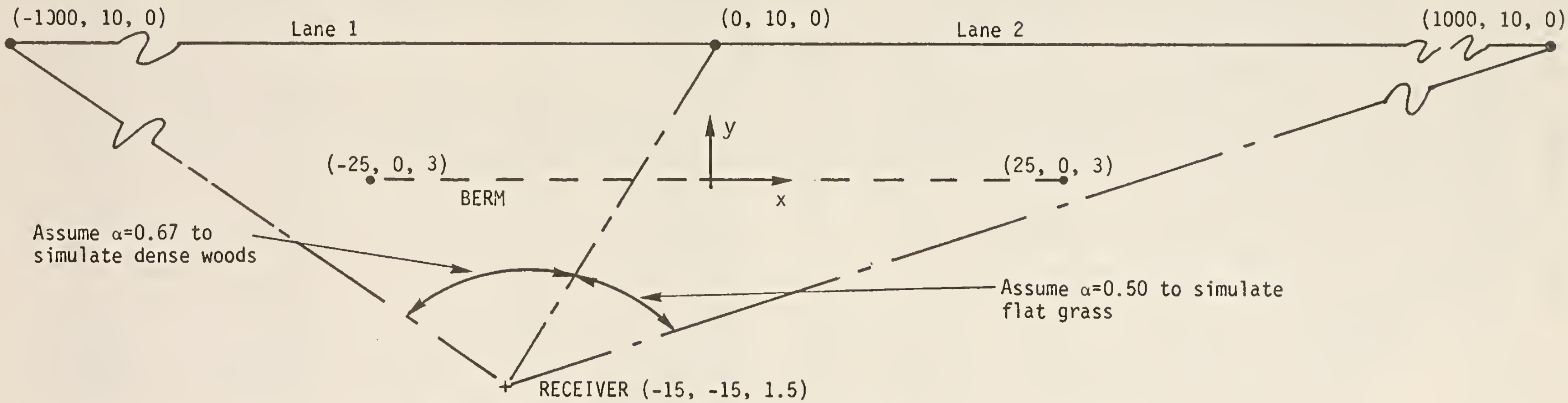
6.2 Example Problem 2: Complete Tabulated Output

This example problem presents the interpretation of the complete tabulated output provided by SNAP 1.0 at the user's option (NOP = 0). Also, the example illustrates how the user may simulate excess distance attenuation for various sections of the site as viewed by the receiver. The traffic flow is modeled using all vehicle types recognized by SNAP 1.0 and defines a "motorcycle" as the user-defined vehicle. A single receiver location is simulated in order to emphasize the calculated results. SNAP 1.0 provides a maximum of eight tabulations (one per page) for each receiver.

Figure 6-5 represents the problem definition in terms of site characteristics. A single infinite straight roadway carries the traffic flow indicated in Figure 6-5. For discussion, the location of the roadway may be assumed to be an "equivalent" lane approximation of a two lane road(1). The roadway elevation is taken as the reference (z = 0) horizontal plane. The proposed berm location and elevation is indicated. The receiver location is placed so that the receiver "sees" the roadway as



(a) Site Plat



(b) SNAP 1.0 Simulation of Site Plat

FIGURE 6-5. EXAMPLE PROBLEM 2: SITE GEOMETRY AND TRAFFIC FLOW DATA

partially blocked by trees on the left and "clear" on the right. To simulate this situation, the single straight equivalent lane is considered to be two connected lanes each with a different "Alpha" value relative to the receiver. The input data are illustrated in Figure 6-6.

As requested, SNAP 1.0 calculates and prints nine tables. The first table lists the program input data. SNAP 1.0 prints the input data only once for each defined lane/barrier configuration. Following the input data tabulation, SNAP 1.0 prints the eight requested (NOP = 0) tables of traffic noise estimates. If more than one receiver location is used, the eight tables are printed for each receiver.

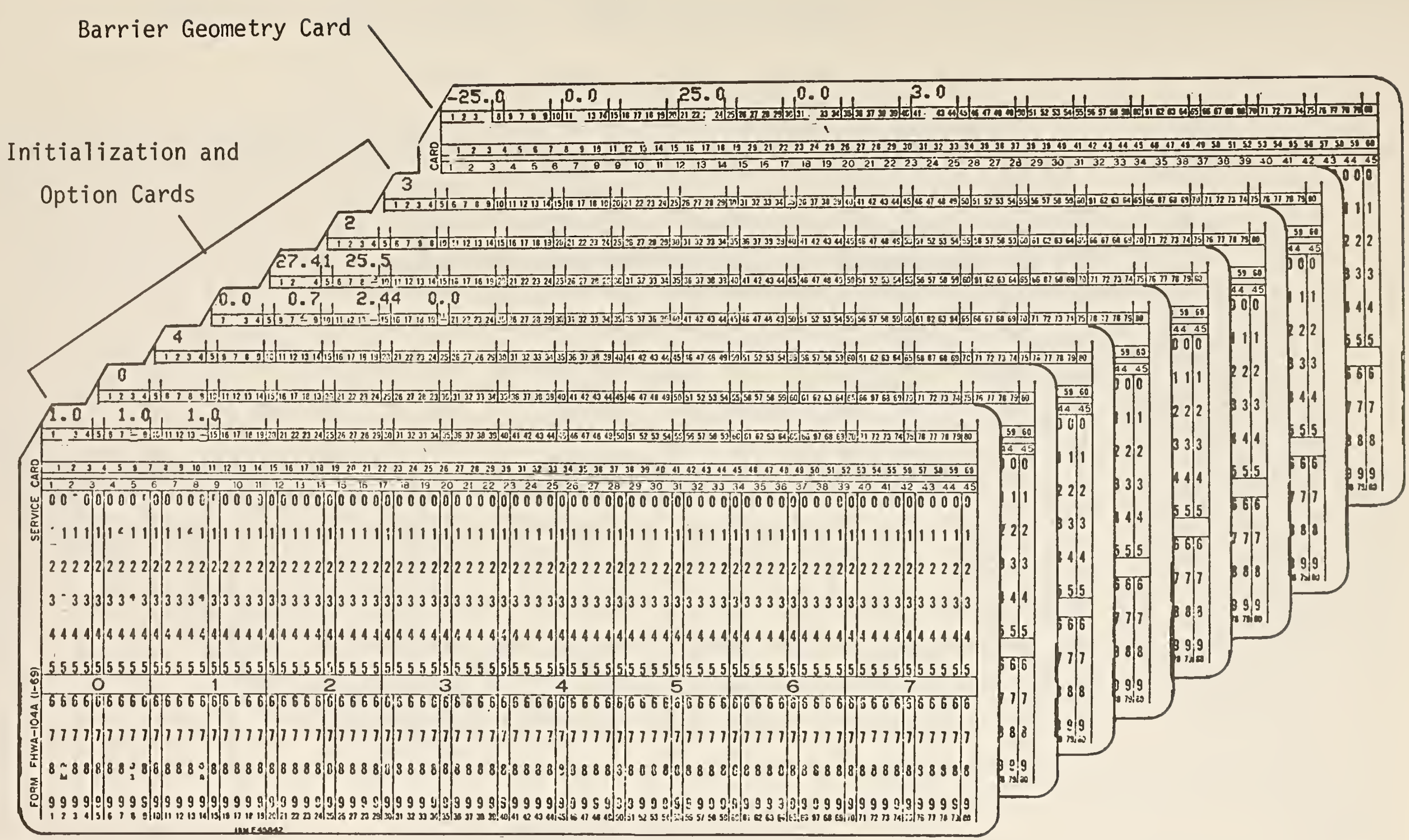
Figure 6-7 illustrates the output tabulation of the input data. Figures 6-8 through 6-15 are the eight standard tabulations (problems) calculated by SNAP 1.0 for each roadway-receiver combination. With the tabulation in each figure is a sketch illustrating the site configuration for estimating receiver sound level contributions.

The standard tabulated output provided by SNAP 1.0 is as follows:

TABLE 1 (Fig. 6-8)	Receiver Sound Level Contributions without the Barrier (This table is always printed).
TABLE 2 (Fig. 6-9)	Receiver Sound Level Contributions with the Barrier (This table is printed if a barrier is defined).
TABLE 3 (Fig. 6-10)	Barrier Field Insertion Loss (Table 1 values less Table 2 values. This table is printed if a barrier is defined).

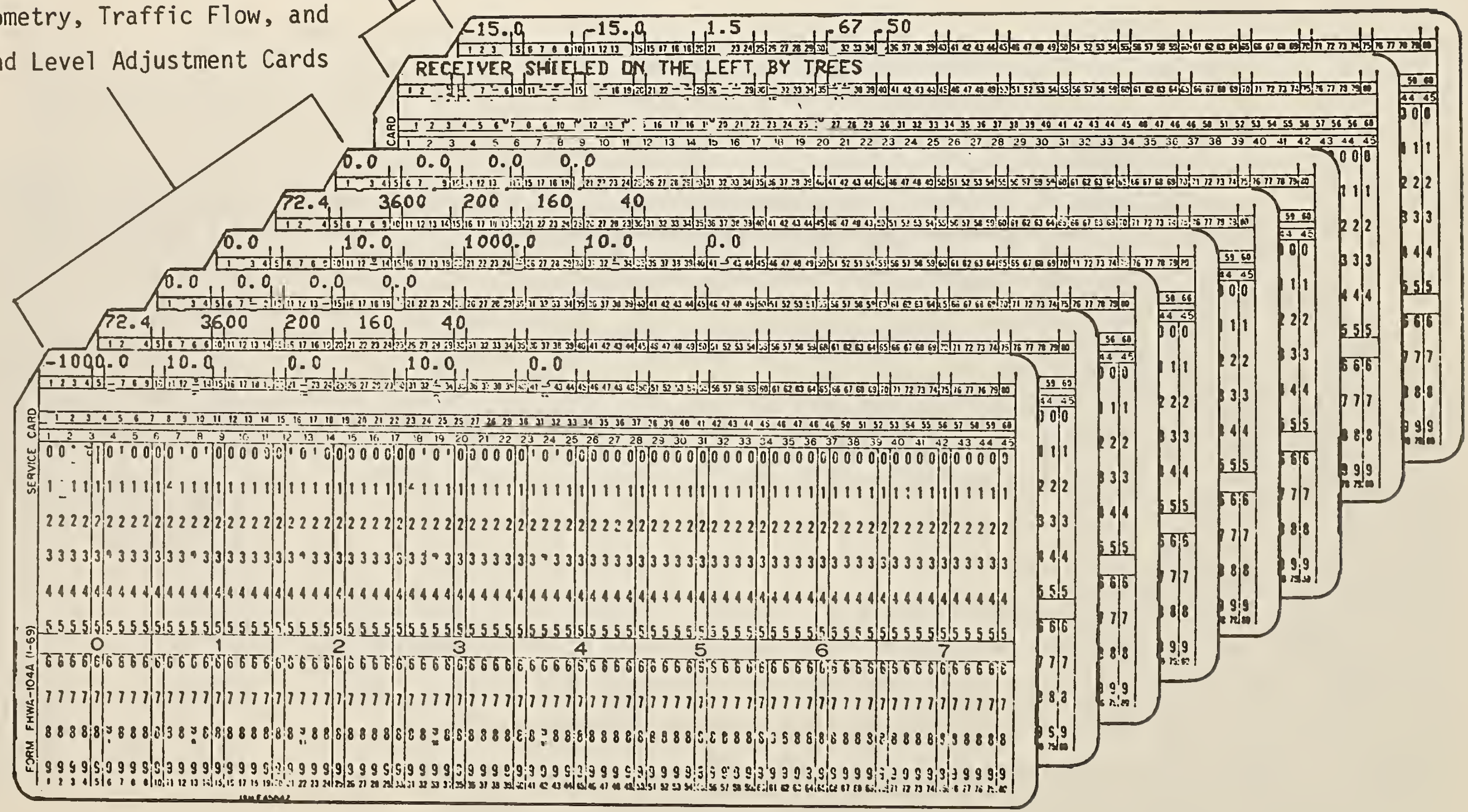
The following tables are printed if the user specifies NOP = 0 and defines a barrier:

TABLE 4 (Fig. 6-11)	Receiver Sound Level Contributions from Lane Segments Potentially Shielded by the Barrier. (These levels are the vehicle/lane contributions from the lane segments that will be shielded by the defined barrier. No barrier attenuation is considered.)
TABLE 5 (Fig. 6-12)	Receiver Sound Level Contributions from Lane Segments Shielded by the Barrier. (These levels are the vehicle/lane contributions from the lane segments shielded by the barrier.)



(See Figures 5-1 through 5-5 and Figure 6-5)

FIGURE 6-6. EXAMPLE PROBLEM 2: INPUT DATA



(See Figures 5-1 through 5-5 and Figure 6-5)

FIGURE 6-6. EXAMPLE PROBLEM 2: INPUT DATA (Concluded)

BASIC INPUT DATA

OPTION DATA

TIME INTERVAL FOR LEQ CALCULATIONS(HR)	=	1.00
EPSILON FOR BARRIER (0=THIN,1=BERM)	=	1.00
CRITERION FOR PARALLELISM(DEG)	=	1.00

SOURCE HEIGHT OF VEHICLES IN METRES

CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
0.0	0.70	2.44	0.0

NOISE LEVEL-SPEED COEFFICIENTS (L0=A+B*LOG(S))

	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
A	-2.43	16.36	38.48	27.41
B	38.05	33.91	24.56	25.50

COORDINATES FOR END POINTS (METRES)

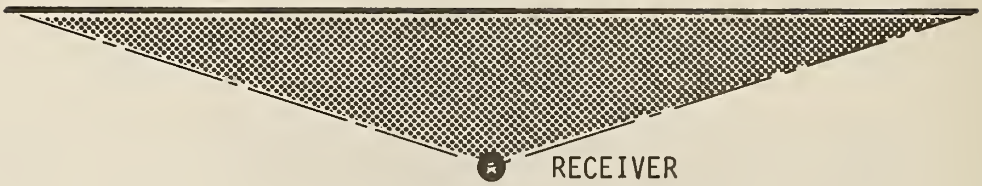
SEGMENT TYPE	X1	Y1	Z1	X2	Y2	Z2
BARRIER	-25.00	0.0	3.00	25.00	0.0	3.00
LANE # 1	-1000.00	10.00	0.0	0.0	10.00	0.0
LANE # 2	0.0	10.00	0.0	1000.00	10.00	0.0

LANE #	SPEED (KM/H)	TRAFFIC VOLUME CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
1	72.4	3600	200	160	40
2	72.4	3600	200	160	40

SOUND-LEVEL ADJUSTMENT PARAMETER

LANE #	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0

FIGURE 6-7. EXAMPLE PROBLEM 2: INPUT DATA TABULATION



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 1

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(NO BARRIER ATTENUATION)

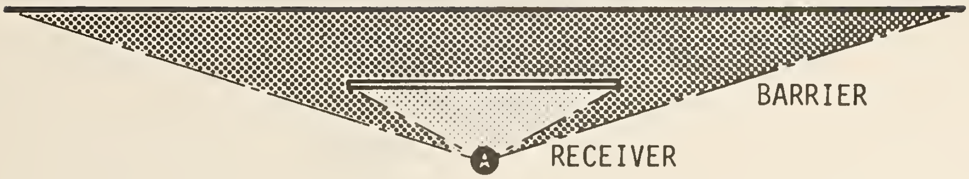
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	65.64	64.18	67.94	52.60	71.04
		L10	67.61	68.16	71.88	53.06	74.47
2	0.50	LEQ	62.12	60.66	64.42	49.08	67.51
		L10	64.09	64.64	68.36	49.54	70.94
VEHICLE		LEQ	67.24	65.78	69.54	54.20	72.63
TOTALS		L10	69.21	69.76	73.48	54.66	76.06

FIGURE 6-8. EXAMPLE PROBLEM 2: TABLE 1 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 2

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(WITH BARRIER ATTENUATION)

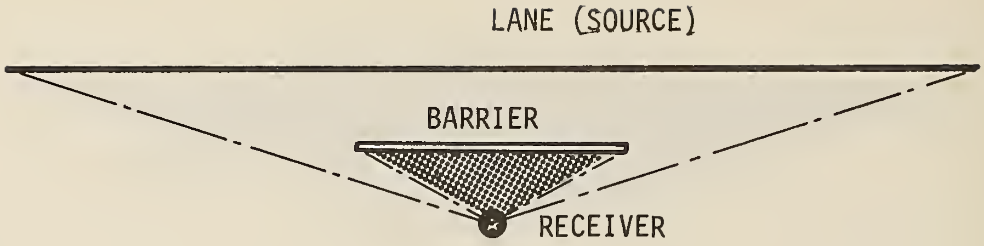
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	61.14	59.77	64.10	48.10	66.89
		L10	63.12	63.72	67.95	48.64	70.30
2	0.50	LEQ	56.02	54.79	59.66	42.98	62.17
		L10	58.01	58.67	63.41	43.66	65.54
VEHICLE		LEQ	62.31	60.97	65.44	49.27	68.15
TOTALS		L10	64.29	64.90	69.26	49.84	71.55

FIGURE 6-9. EXAMPLE PROBLEM 2: TABLE 2 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 3

BARRIER FIELD INSERTION LOSS

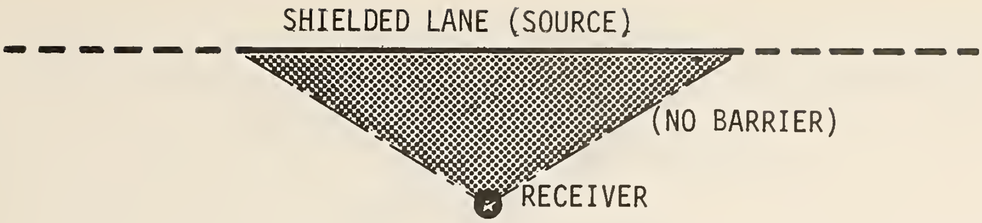
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	4.50	4.41	3.84	4.50	4.15
		L10	4.49	4.45	3.94	4.43	4.17
2	0.50	LEQ	6.10	5.86	4.76	6.10	5.35
		L10	6.08	5.97	4.96	5.88	5.40
VEHICLE TOTALS		LEQ	4.93	4.81	4.10	4.93	4.48
		L10	4.92	4.86	4.23	4.83	4.51

FIGURE 6-10. EXAMPLE PROBLEM 2: TABLE 3 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 4

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

LANE SEGMENTS SHIELDED BY BARRIER
(NO BARRIER ATTENUATION)

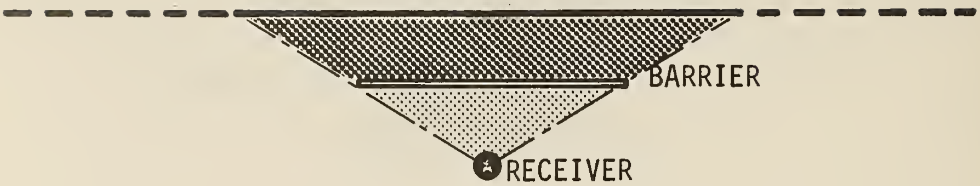
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	63.85	62.39	66.15	50.81	69.24
		L10	65.82	66.37	70.09	51.27	72.67
2	0.50	LEQ	61.09	59.63	63.39	48.05	66.48
		L10	63.06	63.61	67.33	48.51	69.91
VEHICLE		LEQ	65.70	64.23	68.00	52.65	71.09
TOTALS		L10	67.67	68.22	71.94	53.12	74.52

FIGURE 6-11. EXAMPLE PROBLEM 2: TABLE 4 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 5

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

LANE SEGMENTS SHIELDED BY BARRIER
(WITH BARRIER ATTENUATION)

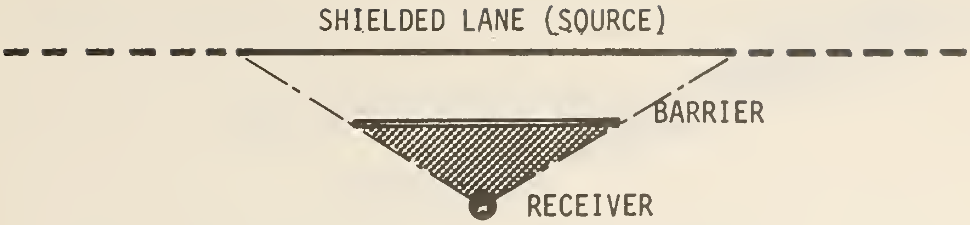
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	47.90	47.99	56.69	34.85	57.74
		L10	49.99	51.39	60.07	36.64	61.00
2	0.50	LEQ	47.54	47.51	55.34	34.50	56.61
		L10	49.63	50.91	58.72	36.29	59.85
VEHICLE		LEQ	50.73	50.77	59.08	37.69	60.22
TOTALS		L10	52.82	54.17	62.46	39.48	63.47

FIGURE 6-12. EXAMPLE PROBLEM 2: TABLE 5 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 6

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

MAXIMUM BARRIER FIELD INSERTION LOSS

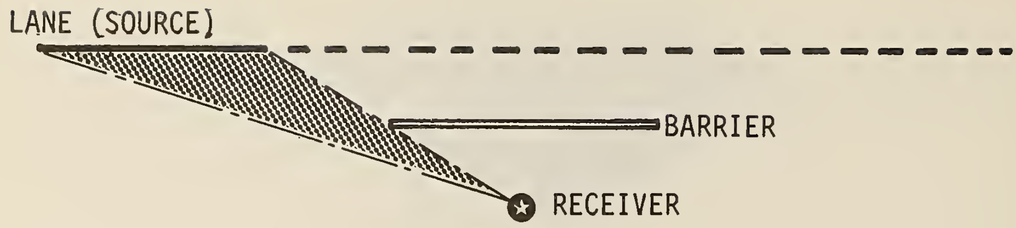
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	15.96	14.40	9.46	15.96	11.50
		L10	15.84	14.98	10.02	14.63	11.68
2	0.50	LEQ	13.55	12.12	8.05	13.55	9.87
		L10	13.43	12.70	8.61	12.22	10.07
VEHICLE		LEQ	14.96	13.47	8.92	14.96	10.87
TOTALS		L10	14.84	14.05	9.48	13.64	11.05

FIGURE 6-13. EXAMPLE PROBLEM 2: TABLE 6 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 7

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

UNSHIELDED LANE SEGMENTS: LEFT OF BARRIER

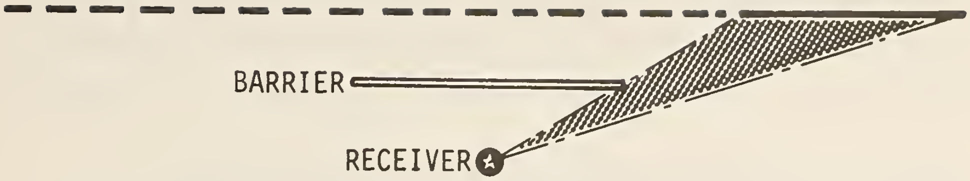
RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	60.93	59.47	63.23	47.89	66.33
		L10	62.90	63.45	67.17	48.35	69.76
2	0.50	LEQ	0.0	0.0	0.0	0.0	0.0
		L10	0.0	0.0	0.0	0.0	0.0
VEHICLE		LEQ	60.93	59.47	63.23	47.89	66.33
TOTALS		L10	62.90	63.45	67.17	48.35	69.76

FIGURE 6-14. EXAMPLE PROBLEM 2: TABLE 7 OUTPUT



FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 8

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

UNSHIELDED LANE SEGMENTS: RIGHT OF BARRIER

RECEIVER SHIELDED ON THE LEFT BY TREES

OBSERVER COORDINATES (METRES)

X	Y	Z
-15.00	-15.00	1.50

LANE NUMBER	ALPHA	SOUND LEVEL METRIC	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.67	LEQ	0.0	0.0	0.0	0.0	0.0
		L10	0.0	0.0	0.0	0.0	0.0
2	0.50	LEQ	55.36	53.89	57.66	42.31	60.75
		L10	57.33	57.88	61.60	42.78	64.18
VEHICLE		LEQ	55.36	53.89	57.66	42.31	60.75
TOTALS		L10	57.33	57.88	61.60	42.78	64.18

FIGURE 6-15. EXAMPLE PROBLEM 2: TABLE 8 OUTPUT

TABLE 6 (Fig. 6-13)	Maximum Barrier Field Insertion Loss (Table 4 values less Table 5 values. This table represents the maximum barrier field insertion loss for the barrier height defined for the problem.
TABLE 7 (Fig. 6-14)	Receiver Sound Level Contribution from Unshielded Segments to the Left of the Barrier. (The term "left" denotes the receiver's left hand side when facing the roadway/barrier system-lane end point #1.)
TABLE 8 (Fig. 6-15)	Receiver Sound Level Contributions from Unshielded Lane Segments to the Right of the Barrier. (Ther term "right" denotes the receiver's right hand side when facing the roadway system-lane end point #2.)

The interpretation of these tables is rather simple. TABLE 1 represents the estimated receiver sound levels for the site without a barrier. TABLE 2 represents the estimated receiver sound levels for the site with the barrier. TABLE 3 is the estimated "field insertion loss" of the barrier, i.e., the dB reduction in traffic noise for the roadway-barrier system.

TABLE 4 is the result analogous to TABLE 1, but SNAP 1.0 considers only subsegments of the defined lanes that are "shielded" by the barrier and excludes barrier attenuation. Shielding is considered to be portions of lanes inside the area defined in the x-y plane by radial lines extending from the receiver through each (x,y) end point of the barrier. For an "infinite" length barrier, TABLE 4 will be identical to TABLE 1.

TABLE 5 is the result analogous to TABLE 2, but SNAP 1.0 considers only subsegments of the defined lanes that are "shielded" by the barrier and includes barrier attenuation. For an "infinite" length barrier, TABLE 5 will be identical to TABLE 2.

TABLE 6 is the maximum barrier field insertion loss and is a measure of the barrier height effectiveness for traffic noise abatement.

Since TABLES 4 through 6 consider only lane segments potentially shielded in the horizontal plane and identify receiver sound level contributions by lane and vehicle type, these results evaluate barrier noise abatement performance by barrier height for a fixed barrier length.

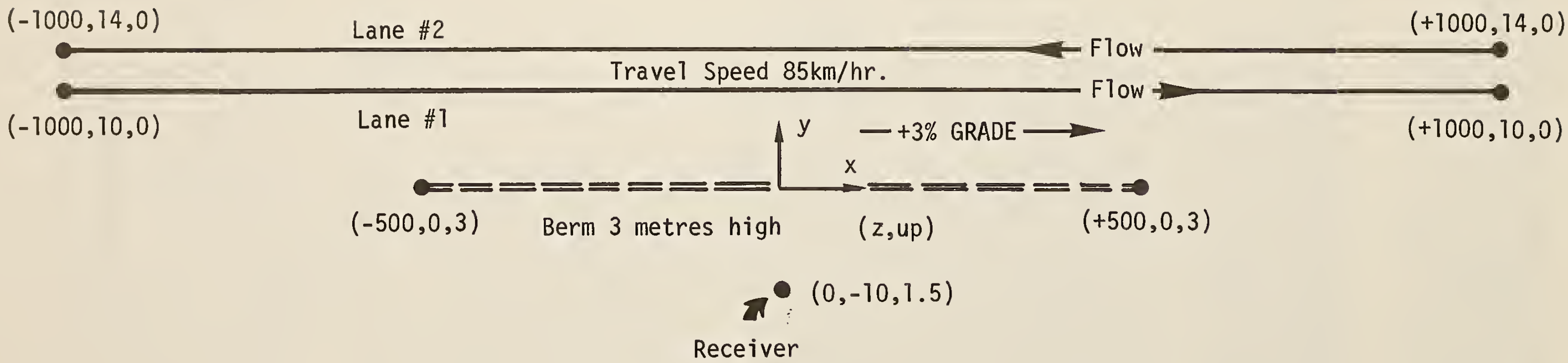
TABLE 7 is the estimated receiver sound level contribution for unshielded lane segments to the receiver's "left" when facing the roadway-barrier system. Extending the barrier to the receiver's left will decrease these levels if the barrier height provides sufficient attenuation.

TABLE 8 is the estimated receiver sound level contribution for unshielded lane segments to the receiver's "right" when facing the roadway-barrier system. Extending the barrier to the receiver's right will decrease those levels if the barrier height provides sufficient attenuation.

The user must always remember that for barrier diffraction SNAP 1.0 assumes that noise propagation in the "shielded" zone is taken as a "hard" site. That is, SNAP 1.0 considers $\alpha = 0$ for diffraction calculations (See Appendix A.2). The estimates printed in TABLES 1, 4, 7, and 8 use the alpha values specified by the input for each receiver-lane combination. The estimates in TABLE 5 assume $\alpha = 0$. The TABLE 2 results consider, as appropriate, the input values of alpha for unshielded lane segments and zero alpha values for the shielded lane segments. TABLES 3 and 6 represent the combined effect of barrier attenuation and replacing "soft" site attenuation with "hard" site attenuation.

6.3 Example Problem 3: Vehicle Sound Level Adjustments

This example problem presents the use of the vehicle sound level adjustment option using SNAP 1.0. The example problem illustrates the adjustments required to account for increased vehicle noise emissions resulting from traffic flowing upgrade. Figure 6-16 illustrates the site geometry and traffic flow data for the example problem.



Traffic Flow Data: Lane #1; 650 cars/hr., 20 medium trucks/hr., 15 heavy trucks/hr.
Lane #2; 650 cars/hr., 20 medium trucks/hr., 15 heavy trucks/hr.

NOTE: Endpoint Coordinates are in the Plane of the Site

FIGURE 6-16. EXAMPLE PROBLEM 3: SITE GEOMETRY AND TRAFFIC FLOW DATA.

Since SNAP 1.0 applies for essentially flat sites, the site geometry used as input data must be expressed relative to the plane of the site. As indicated in Figure 6-16, the two lanes and the top edge of the berm are at a constant elevation with the notation that the site slopes upward at a 3 percent grade in the positive x direction. For this problem, the near lane is the "upgrade" lane for which the sound level adjustments apply.

The discussion in Section 2.4 of this manual indicates that a +3 percent grade would result in a +2 dB sound level adjustment for heavy trucks (Reference 4 data). Hence, this adjustment is applied only for the heavy truck traffic on the near lane (lane No. 1).

Figure 6-17 presents the input data for the problem. Only the standard output tabulations (TABLES 1 through 3) are desired (NOP = 1). Figure 6-18 presents the output tabulations for the example problem. As indicated in the basic input data tabulation, the 2 dB sound level increase was applied only to heavy trucks on lane #1. The receiver hourly L_{eq} exposure is estimated to be 69.7 dB without the berm (TABLE 1 estimate). TABLE 2 estimates are for the site with the berm and indicate an hourly L_{eq} exposure of 59.2 dB. TABLE 3 indicates that the barrier field insertion loss is 10.6 dB.

The example problem was also executed by considering the far lane to be the upgrade lane and the near lane to be downgrade and the site to be flat, i.e., no sound level adjustments. For these different conditions, the hourly L_{eq} estimates are:

	OUTPUT ESTIMATE: $L_{eq}(h)$		
Site Condition	Table 1	Table 2	Table 3
Near Lane Upgrade	69.7	59.2	10.6
Far Lane Upgrade	69.6	59.1	10.6
Flat Site	69.3	58.5	10.8

Hence, the effect of a 3 percent grade upon the sound level estimates for this problem appears to be rather small.

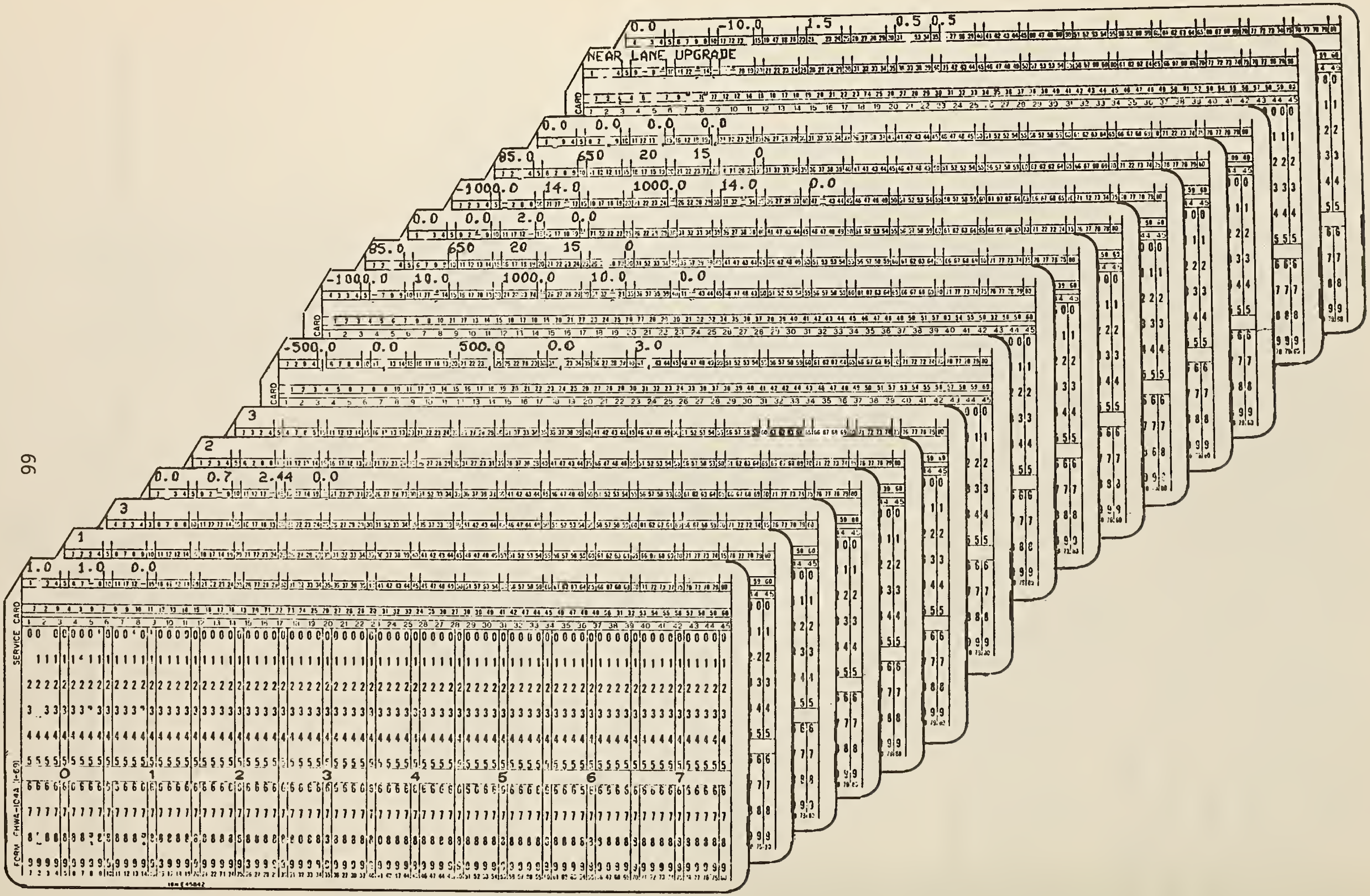


FIGURE 6-17. EXAMPLE PROBLEM 3: INPUT DATA

BASIC INPUT DATA

OPTION DATA

TIME INTERVAL FOR LEQ CALCULATIONS(HR)	=	1.00
EPSILON FOR BARRIER (0=THIN,1=BERM)	=	1.00
CRITERION FOR PARALLELISM(DEG)	=	1.00

SOURCE HEIGHT OF VEHICLES IN METRES

CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
0.0	0.70	2.44	

NOISE LEVEL-SPEED COEFFICIENTS (LO=A+B*LOG(S))

	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
A	-2.43	16.36	38.48	
B	38.05	33.91	24.56	

COORDINATES FOR END POINTS (METRES)

SEGMENT TYPE		X1	Y1	Z1	X2	Y2	Z2
BARRIER		-500.00	0.0	3.00	500.00	0.0	3.00
LANE #	1	-1000.00	10.00	0.0	1000.00	10.00	0.0
LANE #	2	-1000.00	14.00	0.0	1000.00	14.00	0.0

LANE #	SPEED (KM/H)	TRAFFIC VOLUME CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
1	85.0	650	20	15	
2	85.0	650	20	15	

SOUND-LEVEL ADJUSTMENT PARAMETER

LANE #	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER
1	0.0	0.0	2.00	
2	0.0	0.0	0.0	

FIGURE 6-18. EXAMPLE PROBLEM 3: OUTPUT TABULATIONS

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 1

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(NO BARRIER ATTENUATION)

NEAR LANE UPGRADE

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-10.00	1.50

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	63.62	59.30	64.13		67.59
		L10	67.29	52.92	55.92		67.74
2	0.50	LEQ	62.44	58.12	60.95		65.62
		L10	65.97	52.90	53.89		66.43
VEHICLE TOTALS		LEQ	66.08	61.76	65.84		69.73
		L10	69.69	55.92	58.03		70.15

FIGURE 6-18. EXAMPLE PROBLEM 3: OUTPUT TABULATIONS (Continued)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 2

SOUND LEVEL CONTRIBUTIONS AT RECEIVER
ALL LANE SEGMENTS

(WITH BARRIER ATTENUATION)

NEAR LANE UPGRADE

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-10.00	1.50

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	50.51	47.22	55.12		56.91
		L10	53.74	44.90	51.56		56.14
2	0.50	LEQ	50.49	47.04	52.33		55.23
		L10	53.64	45.50	49.55		55.52
VEHICLE TOTALS		LEQ	53.51	50.14	56.95		59.16
		L10	56.70	48.22	53.68		58.85

FIGURE 6-18. EXAMPLE PROBLEM 3: OUTPUT TABULATIONS (Continued)

FHWA HIGHWAY TRAFFIC
NOISE PREDICTION MODEL
(SNAP 1.0)

TABLE 3

BARRIER FIELD INSERTION LOSS

NEAR LANE UPGRADE

OBSERVER COORDINATES (METRES)

X	Y	Z
0.0	-10.00	1.50

LANE #	ALPHA	SOUND LEVEL METRIC	CARS	MEDIUM TRUCKS	HEAVY TRUCKS	OTHER	LANE TOTALS
1	0.50	LEQ	13.11	12.08	9.01		10.69
		L10	13.55	8.02	4.36		11.61
2	0.50	LEQ	11.94	11.08	8.62		10.39
		L10	12.33	7.40	4.35		10.91
VEHICLE		LEQ	12.57	11.62	8.83		10.57
TOTALS		L10	12.99	7.70	4.35		11.30

FIGURE 6-18. EXAMPLE PROBLEM 3: OUTPUT TABULATIONS (Concluded)

REFERENCES

1. Barry, T. M. and Reagan, J. A.: "FHWA Highway Traffic Noise Prediction Model", U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-77-108, July 1978.

2. Rudder, F. F., Jr. and Cheung, P.: "User's Manual FHWA Level 2 Highway Traffic Noise Prediction Model", U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-78-138, July 1978.

3. Ma. Y. Y. and Rudder, F. F., Jr.: "Statistical Analysis of FHWA Traffic Noise Data", U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-78-64, July 1978.

4. Gordon, C. G., et.al.: "Highway Noise, A Design Guide for Engineers", Highway Research Board, National Academy of Sciences, Report NCHRP 117, 1971.

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7. Anon.; "Proposed Motorcycle Noise Emission Regulations: Background Document", U. S. Environmental Protection Agency, Office of Noise Abatement and Control, Report No. EPA 550/9-77-203, November 1977.

APPENDIX A

ACOUSTICS MODEL

This appendix presents the theory upon which the FHWA Level 1 highway traffic noise prediction program is based. The first section presents the basis for the equivalent sound level estimation at the receiver for roadway lanes unshielded by a barrier. The second section describes the calculation of the equivalent sound level at a receiver location shielded by a barrier. The results of Sections A.1 and A.2 are based upon the theory derived in Reference A-1. Section A.3 describes the approximations upon which the conversion of L_{eq} estimates to L_{10} estimates are based.

The basic problem analyzed by the FHWA Level 1.0 model is presented in Figure A-1. The only restriction assumed by the model is that a barrier and all traffic lanes are parallel to each other.

A.1 Equivalent Sound Level

For a traffic lane segment unshielded by a barrier, the equivalent sound level at the receiver due to a single vehicle type is [A-1]*:

$$L_{eq}(T)_{ij} = (\overline{L}_o)_{Eij} + 10\log\left(\frac{N_{ij}D_o}{TS_j}\right) + 10(1+\alpha_j)\log(D_o/D_j)$$

$$+ 10\log\left\{\Psi_{\alpha j}(\phi_{1j}, \phi_{2j})\right\} - 30 \text{ dB} \qquad \text{(A-1)}$$

where** $\Psi_{\alpha j}(\phi_{1j}, \phi_{2j}) = \int_{\phi_{1j}}^{\phi_{2j}} [\cos(\phi)]^{\alpha_j} d\phi$

$$-\pi/2 \leq \phi \leq \pi/2$$

Subscript i denotes a vehicle type

Subscript j denotes the traffic lane.

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* Numbers in [ ] in the text denote references listed at the end of the appendix.

** This definition differs from that of Reference A-1 by a factor of $1/\pi$.

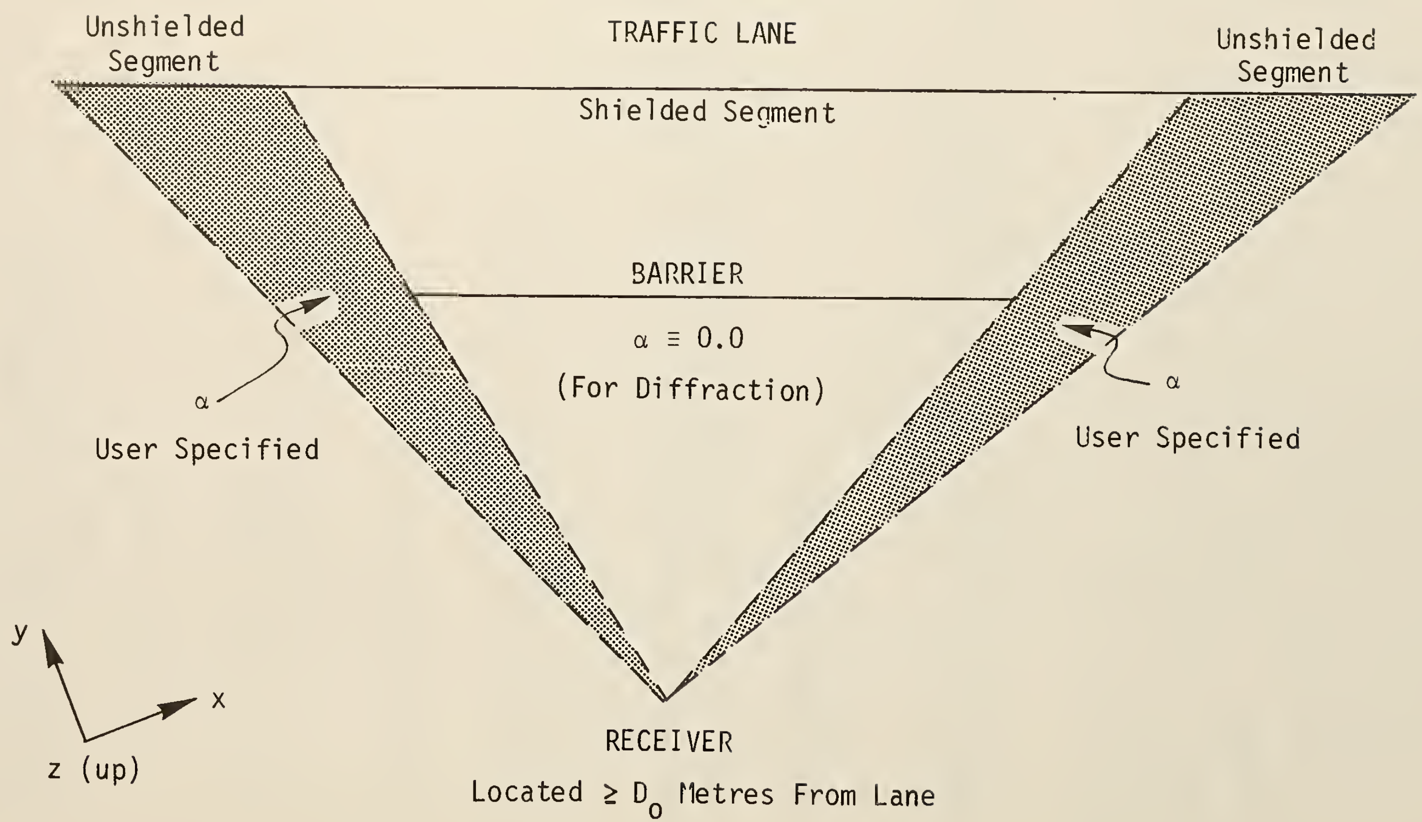

FIGURE A-1. PLAN VIEW OF TRAFFIC LANE - RECEIVER RELATIONSHIP

Definitions of the terms appearing in Equation (A-1) are presented at the end of the appendix. The only general restrictions on the result of Equation (A-1) are that the receiver distance, D_j, must be equal to or greater than the reference distance, D_o, and that distances are expressed in metres and speed in kilometres per hour.

The basic parameter in Equation (A-1) is the vehicle reference energy mean emission level, $(\overline{L}_o)_{Eij}$. The subscripts (i, j) are used to denote the vehicle type (i) and the traffic speed, S_j, on the j^{th} traffic lane.

Based upon the results of Reference A-2 , the vehicle reference energy mean emission levels are:

Automobiles and Light Trucks $\quad (\overline{L}_o)_{E1j} = -2.43 + 38.05\log(S_j) \quad$ (A-2a)

Medium Trucks $\quad (\overline{L}_o)_{E2j} = 16.36 + 33.91\log(S_j) \quad$ (A-2b)

Heavy Trucks $\quad (\overline{L}_o)_{E3j} = 38.48 + 24.56\log(S_j) \quad$ (A-2c)

"Other" Vehicles $\quad (\overline{L}_o)_{E4j} = A_4 + B_4\log(S_j) \quad$ (A-2d)

Generally, light trucks will be two-axle trucks with a gross vehicle weight less than 4536 kg*. Medium trucks are two-axle trucks with a gross vehicle weight greater than 4536 kg but less than 11,793 kg. Heavy trucks are trucks with three or more axles and a gross vehicle weight exceeding 11,793 kg. The reference distance, D_o, to which the results of Equations (A-2) apply is 15.0m from the vehicle line of travel. Also, the results of Equations (A-2) apply only for vehicle speeds in the range: $50 \text{ km/h} \leq S_j \leq 100 \text{ km/h}$. All parameters used in Equation (A-1) must represent average values for the time period of T hours.

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* kg denotes kilograms force or Newtons.

The result of Equation (A-1) is evaluated in the program by FUNCTION ALEQ(I,J). The vehicle reference energy mean emission levels are evaluated by SUBROUTINE LLL with the coefficients stored in BLOCK DATA. The coefficients for the user-defined "other vehicle" are read as input data.

For lane-receiver locations such that the receiver is close to the center line extension of the lane but beyond the reference distance, D_o, the equivalent sound level at the receiver is expressed as [A-1]:

$$L_{eq}(T)_{ij} = (\overline{L}_o)_{Eij} + 10\log\left(\frac{N_{ij}D_o}{TS_j}\right) - 10\log(1+\alpha_j)$$

$$+ 10\log\left((D_o/R_{nj})^{1+\alpha_j} - (D_o/R_{fj})^{1+\alpha_j}\right) - 30 \quad \text{dB} \qquad \text{(A-3)}$$

FUNCTION ALEQ(I,J) checks the lane-receiver geometry and uses either Equation (A-1) or (A-3) as appropriate to estimate the value of, $L_{eq}(T)_{ij}$.

A.2 Barrier or Berm Attenuation

For a lane segment shielded by a berm or a barrier, the equivalent sound level at the receiver due to a single vehicle type is [A-1]:

$$L_{eq}(T)_{ij} = (\overline{L}_o)_{Eij} + 10\log\left(\frac{N_{ij}D_o}{TS_j}\right) + 10\log(D_o/D_j) + \Delta_{Bij} - 30 \quad \text{dB} \qquad \text{(A-4)}$$

where $$\Delta_{Bij} = 10\log\left\{\int_{\phi_{1j}}^{\phi_{2j}} F_{ij}(\phi)d\phi\right\}$$

The function $F_{ij}(\phi)$ estimates the attenuation of the sound level at the receiver from a point on the lane. The geometry associated with the diffraction of sound from the lane to the receiver is illustrated in Figure A-2. By assuming that the upper edge of the barrier or the berm is parallel to the lane,* the Fresnel Number may be approximated by the relationship (See Figure A-2):

$$\overline{N}_{ij}(\phi) = \overline{N}_{oij}\cos(\phi) = (2f/c)\delta_{oij}\cos(\phi) \qquad \text{(A-5a)}$$

Since the FHWA Level 1.0 highway traffic noise prediction model is based upon an A-weighted sound level metric, it is assumed that a "representative" frequency for the sound level spectra of all vehicles is f=550Hz. Further, it is assumed that a representative speed of sound is c=343 m/s. With these assumptions, the Fresnel Number is approximated as [A-1]:

$$\overline{N}_{ij}(\phi) = (2\cdot 550/343)\delta_{oij}\cos(\phi) = 3.207\delta_{oij}\cos(\phi) \qquad \text{(A-5b)}$$

Further, assuming that berms provide 3dB more attenuation than thin screen barriers, the attenuation function $F_{ij}(\phi)$ may be approximated as [A-1]:

$$F_{ij}(\phi) = 1.0 \quad \text{for } \overline{N}_{ij}(\phi) \le -0.1916-0.0635\,\varepsilon \qquad \text{(A-6a)}$$

$$F_{ij}(\phi) = 10^{-(5+3\varepsilon)/10}\,\mathrm{TAN}^2(\sqrt{X_{ij}})/X_{ij}$$
$$\text{for } -0.1916-0.0635\varepsilon \le \overline{N}_{ij}(\phi) \le 0 \qquad \text{(A-6b)}$$

$$F_{ij}(\phi) = 10^{-(5+3\varepsilon)/10}\,\mathrm{TANH}^2(\sqrt{X_{ij}})/X_{ij}$$
$$\text{for } 0 \le \overline{N}_{ij}(\phi) \le 5.03 \qquad \text{(A-6c)}$$

$$F_{ij}(\phi) = 10^{-(20+3\varepsilon)/10}$$
$$\text{for } \overline{N}_{ij}(\phi) \ge 5.03 \qquad \text{(A-6d)}$$

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*This assumption causes the parallelism restriction on the geometric formulation of SNAP 1.0 problems.

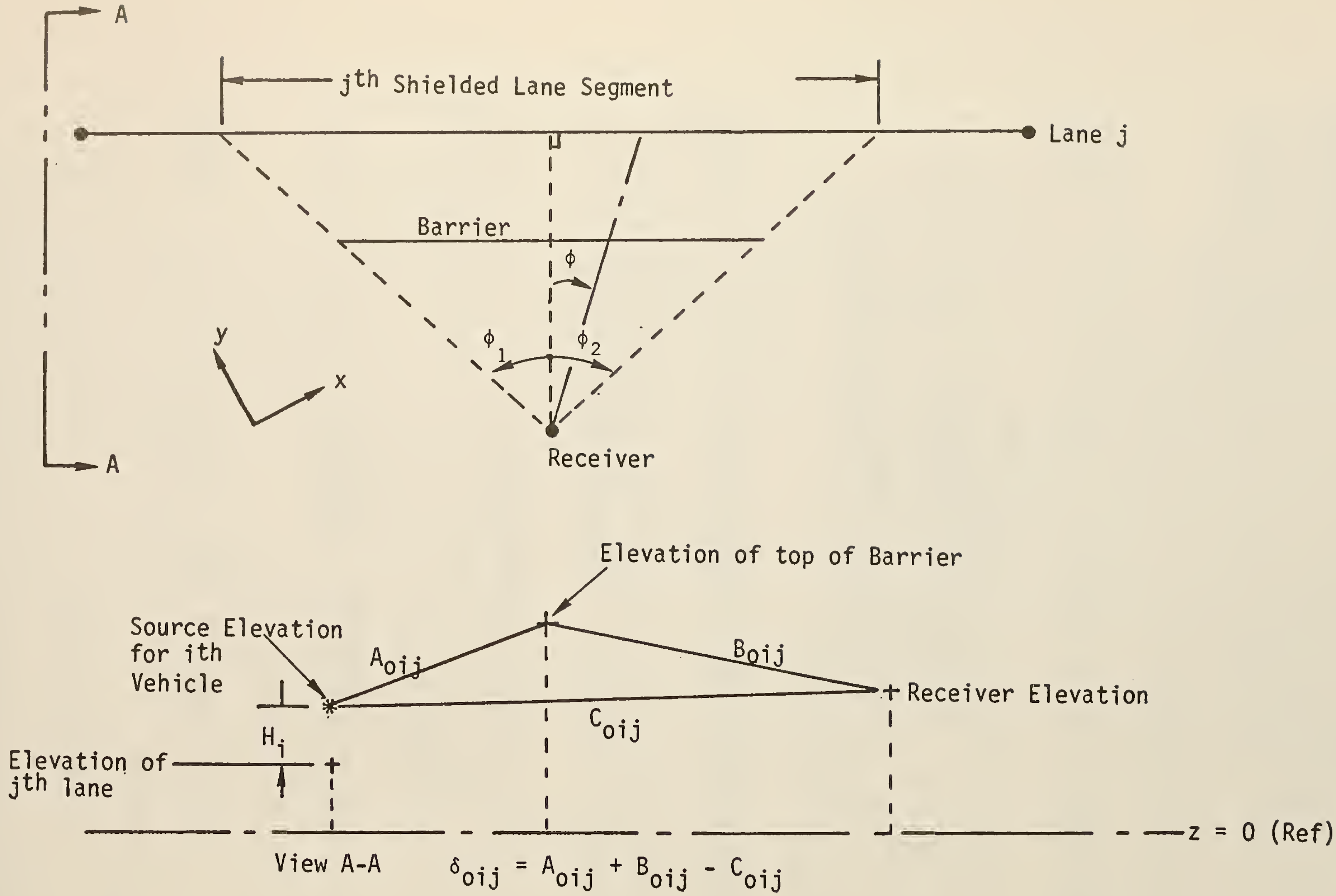

FIGURE A-2. BARRIER DIFFRACTION GEOMETRY

where $\quad X_{ij} = 2\pi | \overline{N}_{ij}(\phi)|$

ε = 0.0 for a thin screen barrier

ε = 1.0 for a berm

Figure A-3 presents the barrier attenuation Function, $F_{ij}(\phi)$, plotted versus the Fresnel Number, $\overline{N}_{ij}(\phi)$. The subscripts (i, j) are included in Equation (A-6) to emphasize that for a given lane (j), each vehicle type (i) may represent to the receiver a different source height and, hence, a different path length difference δ_{oij}.

A.3 L_{eq} to L_{10} Conversion

The FHWA Level 1 highway traffic noise prediction model uses the equivalent sound level metric, L_{eq}, as the basic descriptor of highway traffic noise generation. The theory of Sections A.1 and A.2 is rather firmly based upon physical considerations. The estimation of percentile sound levels, such as the L_{10} metric, is a very difficult task to perform accurately. However, it appears that the difference between the L_{eq} and the L_{10} metrics for identical traffic flows may be estimated much more easily than a direct estimation of the L_{10} level [A-3]. It appears [A-3] that the difference, $\Delta_{10} = L_{10}-L_{eq}$, is a function of the parameter A = ND/S. The parameter, A = ND/S, combines the traffic flow rate (N vehicles per hour), the receiver distance (D in metres) and the traffic flow speed (S in kilometres per hour). Additionally, the difference between the L_{10} metric and the L_{eq} metric may be expected to vary with the site parameter, α.

The requirement to convert the equivalent sound level metric, L_{eq}, to the percentile metric, L_{10}, is then simply to determine an approximation to the level difference, $L_{10}-L_{eq}$, as a function of the parameter A = ND/S. Also, it would be desirable to include the site effects, as considered by the parameter, α, in the conversion. Little experimental evidence is available, however, to support this methodology.

"Berm" Attenuation: $\varepsilon = 1.0$

"Thin Screen" Attenuation: $\varepsilon = 0.0$

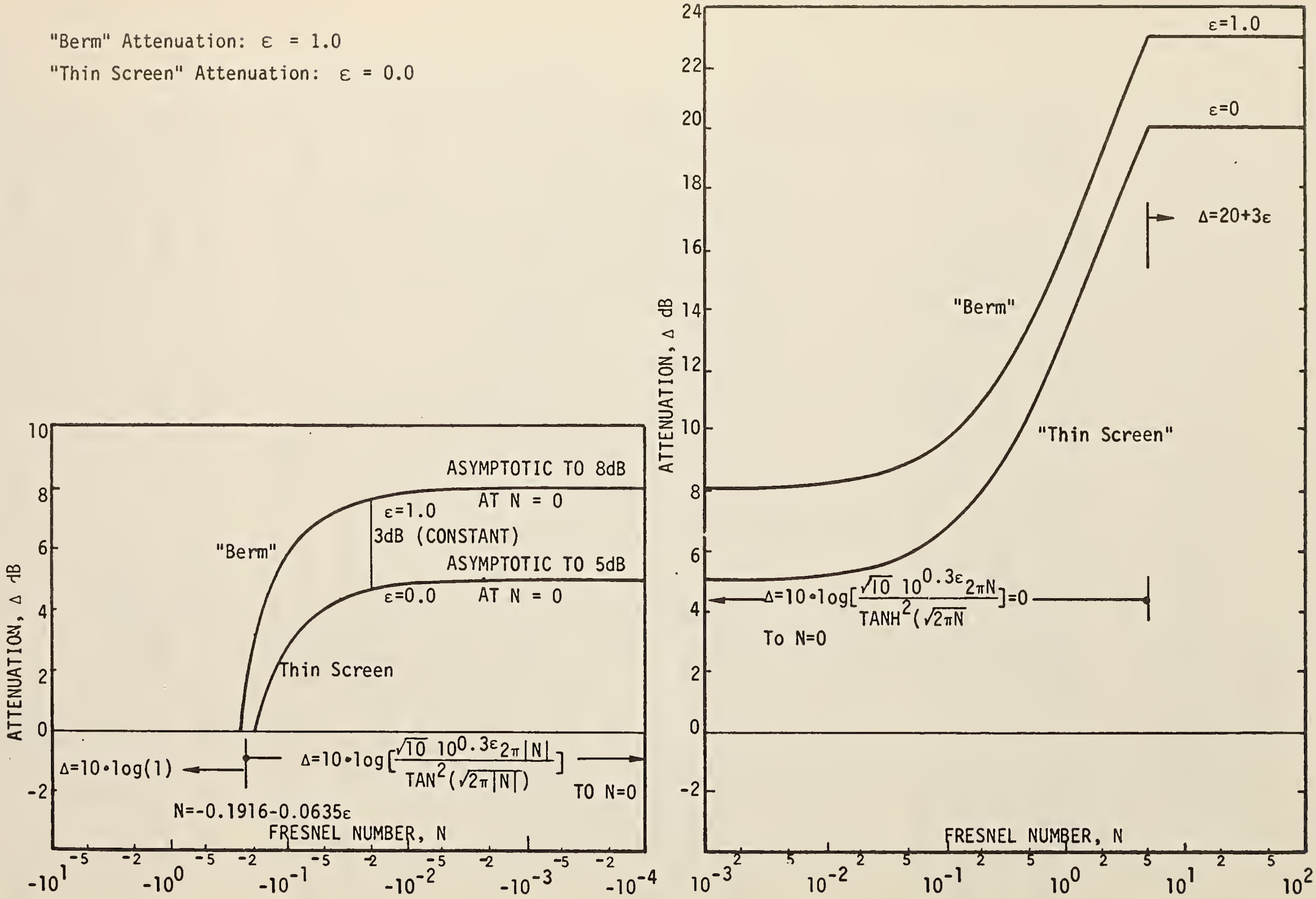

FIGURE A-3. BARRIER ATTENUATION AS A FUNCTION OF FRESNEL NUMBER

NOTE: ATTENUATION IS FOR A POINT SOURCE

Proceeding on this basis, the results and data of References A-1 through A-5 were reviewed. Following the approach taken by Reference A-3, the theory of References A-1 and A-5 were used to obtain approximations to the level difference:

$$\Delta_{10}(A,\alpha) = L_{10}(A,\alpha) - L_{eq}(A,\alpha) \qquad \text{(A-7)}$$

for both "low" values of A and "high" values of A.

Physically, "low" values of the parameter A = ND/S represent traffic flows for which each vehicle appears to the receiver as an isolated "single event". The term "high" values of the parameter A = ND/S imply traffic flow conditions for which the instantaneous sound level at the receiver is contributed from many sources along the roadway. In Equation (A-7), the functional form of the result implies that the conversion depends upon both the parameter A and the parameter α.

Using the methodology of Reference A-3 and applying the analysis of Reference A-1, the functional forms of Equation (A-7) were obtained for both "low" and "high" values of A as a function of the site parameter α. To provide a smooth transition of this functional relationship between the theoretical limits of "high" A and "low" A, a smooth functional form was assumed. This functional form was used to obtain the following estimates:

$$\Delta(A_{ij}) = L_{10ij} - L_{eqij} \qquad \text{(A-8)}$$

$$A_{ij} = N_{ij}\, D/S_j$$

For a "hard site" (Evaluated for $\alpha = 0.0$):

$$\Delta(A_{ij}) = -8.98 + 9.8788\log(A_{ij}) \qquad \text{for } 1 \le A_{ij} \le 8.11 \text{ m/km}$$

$$\Delta(A_{ij}) = 9.8788(A_{ij}/8.11)^{-0.46395} \times \log(A_{ij}/8.11) \quad \text{for } A_{ij} \ge 8.11 \text{ m/km} \qquad \text{(A-9)}$$

For a "soft site" (Evaluated for $\alpha = 0.50$):

$$\Delta(A_{ij}) = -16.28 + 14.6924\log(A_{ij}) \qquad \text{for } 1 \leq A_{ij} \leq 12.825 \text{ m/km}$$

$$\Delta(A_{ij}) = 14.6924(A_{ij}/12.825)^{-0.58924} \times \log(A_{ij}/12.825) \text{ for } A_{ij} \geq 12.825 \text{ m/km}$$

(A-10)

The results of Equations (A-9) and (A-10) are presented in Figure A-4. These results are coded in FUNCTION DELK in the FHWA Level 1 prediction program. Since the L_{eq} to L_{10} conversion is an approximation, the user may consider the L_{10} estimates as more of a "reasonable" result than an accurate estimate.

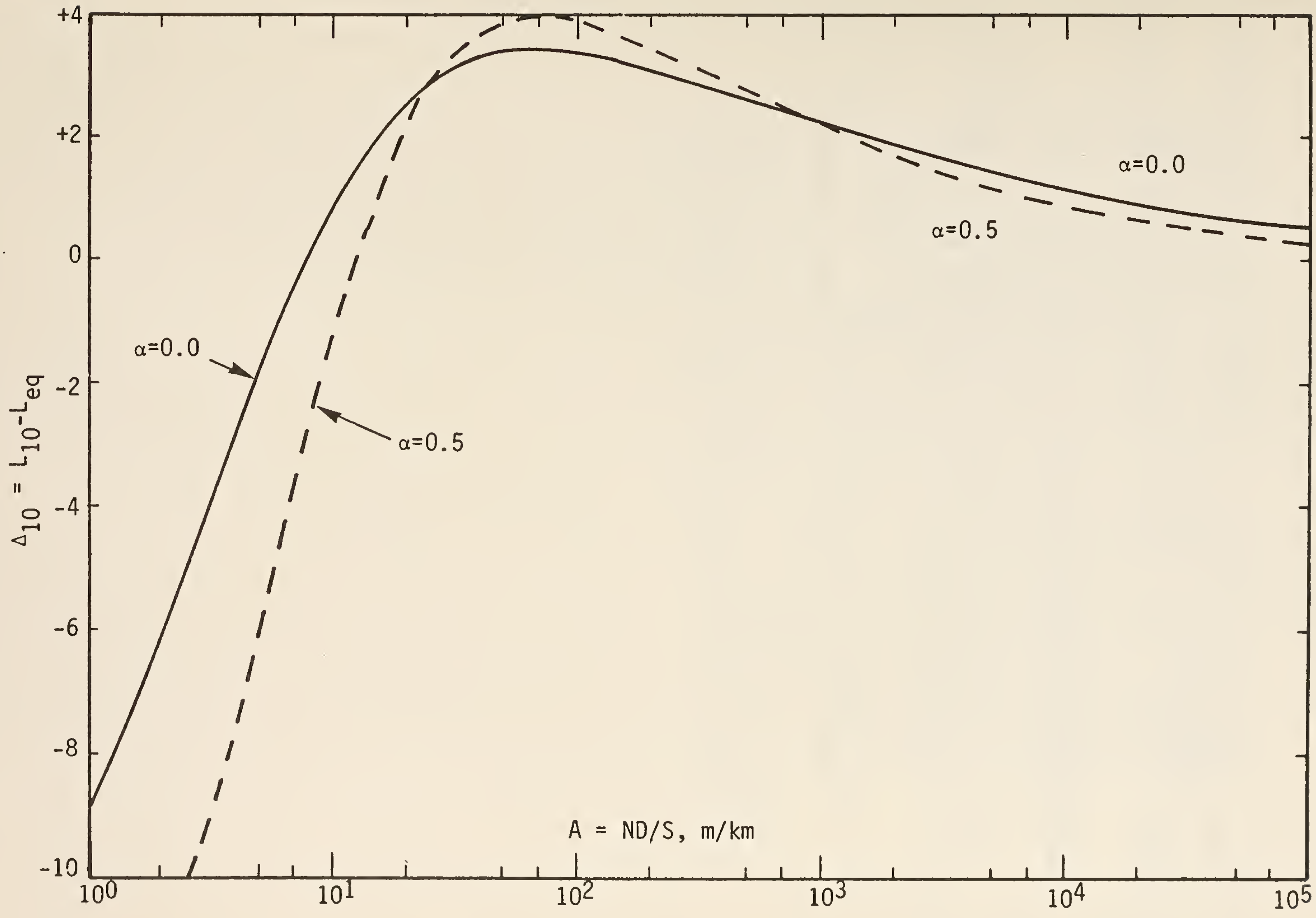

FIGURE A-4. L_{eq} TO L_{10} CONVERSION

DEFINITION OF TERMS IN EQUATION (A-1)

$L_{eq}(T)_{ij}$	Equivalent sound level at receiver due to the ith vehicle type on the jth lane
$(\bar{L}_o)_{Eij}$	The reference A-weighted energy mean emission level for the ith vehicle type at the operating speed of the jth lane
N_{ij}	The number of vehicles of type i operating on lane j in the time period of T hours
D_o	The reference distance for evaluating $(\bar{L}_o)_E$ (15. metres)
T	The time period, in hours, for vehicle N_{ij} and S_j apply
S_j	The average operating speed, in kilometres per hour, for the time period T hours.
α_j	The excess distance attenuation factor applicable for the jth lane
D_j	The distance, in metres, of the receiver from the jth lane.

REFERENCES - APPENDIX A

1. Barry, T. M. and Reagan, J.A.: "FHWA Highway Traffic Noise Prediction Model", U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-77-108, July 1978.

2. Ma, Y. Y. and Rudder, F. F., Jr.: "Statistical Analysis of FHWA Traffic Noise Data", U.S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-78-64

3. Anon.: "Highway Noise: Generation and Control", National Cooperative Highway Research Program, Report 173, Transportation Research Board, National Research Council, Washington, D. C., 1976, pp. 137-139.

4. Kurze, U. J.: "Noise From Complex Road Traffic", Journal of Sound and Vibration, Vol. 19, No. 2, 1971, pp. 167-177.

5. Rudder, F. F., Jr. and Cheung, P.: "FHWA Level 2 Highway Traffic Noise Prediction Model:, U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-78-138 , January 1979.

APPENDIX B
DECLARED SIZE OF ARRAYS

B.1 Subscripts defining the Size of Arrays

Three subscripts define the size of arrays used by SNAP 1.0. These subscripts are as follows:

I denotes a vehicle type and has a declared size of 4 for SNAP 1.0. The subscript I defines:

I=1, Automobiles and Light Trucks

I=2, Medium Trucks

I=3, Heavy Trucks

I=4, User Defined Vehicle

Increasing the declared value of I=4 would require reprogramming the tabular output format.

J denotes a straight line segment defining the location of a barrier or a lane. The following convention is used by SNAP 1.0:

J=1 denotes a barrier*

J=2, ...,13 denotes a lane numbered from 1 to 12.

Increasing the declared value of J=13 may result in tabulations exceeding one printed page.

K denotes a coordinate point in (x,y,z) space. The (x,y) coordinates define the point location in the horizontal plane. The z coordinate denotes the vertical location of a point. The following convention is used by SNAP 1.0:

K=1, denotes the x coordinate

K=2, denotes the y coordinate

K=3, denotes the z coordinate

K=4, denotes the length of a line.

This convention cannot be altered without reprogramming SNAP 1.0.

---

* Only for IBAR=2. If IBAR=1 (i.e., no barrier), J=1, . . ., 12 denotes a lane.

B.2 General Array Sizes

The following declared array sizes are presented for reference. The user should consider the comments in Section B.1 before altering any array sizes. Definition of variables appears in the appropraite description of the MAIN Program, BLOCK DATA, or the subprograms.

- ITITLE(10) - 40 Alphanumeric Characters

Vehicle Parameters; Subscript I
A(I), B(I), H(I), DDV(I), DDRV(I), DDLV(I), DD10DV(I), DD10RV(I), DD10LV(I), PPV(I), PP10V(I), LEQV(I), L10V(I), BLEQV(I), BL10V(I), DLEQV(I), DL10V(I).

Barrier/Lane Parameters; Subscript J
ALPHA(J), S(J),A01(J), A02(J), DDDR(J), DDRR(J), DDLR(J), DD10R(J), DD10LR(J), DD10RR(J), PPR(J), PP10R(J), LEQR(J), L10R(J), BLEQR(J), BL10R(J), DLEQR(J), DL10R(J).

Points, Subscript K=3: X0(3)

Points Defining Barrier/Lane Geometry; Subscripts (K=3, J)
XR1(3,J), XR2(3,J)

Vectors Defining Directed Line Segments: Subscripts (K=4,J)

D01(4,J), D02(4,J), DR(4,J), UR(4,J), P0(4,J), Q0(4), Z0(4), ZAP(4)

Vehicle/Lane Parameters; Subscripts (I, J>1)   AA(I,J), AL0(I,J), J(I,J), DDD(I,J), DDR(I,J), DDL(I,J), PP(I,J), DD10D(I,J), DD10L(I,J), DD10R(I,J), PP10(I,J), LEQ(I,J), L10(I,J), BLEQ(I,J), BL10(I,J), DLEQ(I,J), DL10(I,J)

APPENDIX C
ARCHITECTURE OF PROGRAM

The FHWA Level 1 highway traffic noise prediction model is intended for quick execution of simple problems. This version, SNAP 1.0, is written in FORTRAN IV language and is intended to run in the batch mode. Input data is via a card reader and output is via a line printer (See BLOCK DATA and COMMON/A).

C.1 MAIN Program Description

The MAIN program controls the overall data management to perform the highway traffic noise predictions using the SNAP 1.0 formulation. The MAIN program calls various subprograms that conduct the bulk of the calculations.

The MAIN program reads, audits, and prints all input data required to define a problem other than the receiver location. The only audit or check on the input data is the criterion for parallelism. If line segments (defined by the input values of the end point coordinates) are not parallel within the specified criterion (THETA), execution of SNAP 1.0 is halted (SUBROUTINE MESS1).

Following the successful printing of the input data, SNAP 1.0 reads the title card for the receiver location. If the title card is not present (as the case for the end of a multi-receiver problem), SNAP 1.0 halts execution. Following the receiver title card, the receiver location/alpha card is read. This completes a problem definition for SNAP 1.0.

SNAP 1.0 then initializes the values of all the tabulation arrays to zero. By calling SETUP, SNAP 1.0 calculates all the basic geometric data required to locate the receiver relative to each lane and the barrier. If a receiver is too close to a lane (i.e., within 15. m), SETUP prints a fatal error message (SUBROUTINE MESS2) and halts execution.

Following the exit from SETUP, SNAP 1.0 checks to see if the receiver is located too close to the barrier (i.e., within 0.5m). If the receiver is too close, SNAP 1.0 prints a fatal error message (SUBROUTINE MESS3) and halts execution.

SNAP 1.0 next calculates the receiver sound levels for the site without the barrier and prints TABLE 1. If the user has not defined a barrier (IBAR=1), SNAP 1.0 reads the next receiver title card and location/alpha card and repeats the TABLE 1 execution until the last receiver has been considered.

If the user has defined a barrier, SNAP 1.0 automatically calculates and prints the receiver sound levels with barrier attenuation (TABLE 2) and the barrier field insertion loss (TABLE 3). If the user has declared NOP = 1, SNAP 1.0 reads the next set of observer cards and repeats the calculation printing TABLES 1, 2 and 3 for each receiver.

If the user has declared NOP = 0, SNAP 1.0 continues its calculations printing, in turn, TABLES 4 through 8 for the receiver. Upon completing this task, SNAP 1.0 repeats the calculation and printing of TABLES 1 through 8 for each subsequent receiver location defined by the user.

C.2 MAIN Program Variable List

The following is a list of variables used in the MAIN program.

T	Time period for which L_{eq} is computed
EPS	Barrier parameter (EPS=0 thin screen; EPS=1 berm)
THETA	Criterion for parallelism in degrees
NOP	Option to print tables (NOP=0 print all 8 tables; NOP=1 print only 3 tables)
NI	Number of vehicle types

AA(I,J)	Sound Level Adjustment: Vehicle Type I on Lane J
H(I)	Height of vehicle type I
A(I)	Constant term in sound level - speed relation
B(I)	Log coefficient in sound level-speed relation
IBAR	Indicates existence of barrier (IBAR=1, no barrier; IBAR=2 with barrier)
NJ	Number of lane segments (including barrier)
S(J)	Speed of lane J
N(I,J)	Number of vehicle of type I on lane J for the time period T
ALPHA(J)	α for lane J
ITITLE	40 characters describing the title of the receiver
XR1(K,J)	Coordinates of end point 1 of lane J in 3-space
XR2(K,J)	Coordinates of end point 2 of lane J in 3-space
XO(K)	Coordinates of receiver in 3-space
DR(K,J)	Vector of end point 2 of lane J relative to end point 1
PO(K,J)	Vector of normal to lane J from receiver
ZO(K)	Coordinates of end point of PO
AO1(J)	Angle between normal and end point 1 of lane J to receiver
AO2(J)	Angle between normal and end point 2 of lane J to receiver
ZAP(K)	Unit vector in the z direction
PHI1	Lower limit angle for integration
PHI2	Upper limit angle for integration
LEQ(I,J)	L_{eq} for vehicle I, lane J
L10(K,J)	L_{10} for lane J, summed over I
LEQR(J)	L_{eq} for lane J, summed over I
L10R(J)	$L_{10}$for lane J, summed over I
LEQV(I)	L_{eq} for vehicle I, summed over J
L10V(I)	L_{10} for vehicle I, summed over J
LEQT	L_{eq} summed over I and J
L10T	L_{10} summed over I and J
BLEQ etc.	Same as above, but with barrier
DDD etc.	Same as above, but for barrier shielded portion
PP etc.	Same as above, but for barrier shielded portion with barrier removed
DDR etc.	Same as above, but for portion left of barrier
DDL etc.	Same as above, but for portion right of barrier

```
                C
                C FHWA MANUAL METHOD
                C
0001                  COMMON/ABBLE/FC,I,J,M1,M2,IN,MOUT,ITITLE(10),KA
0002                  COMMON/BETA/A(4),B(4),DC,AA(4,13)
0003                  COMMON/CAT/XO(3),NI,NJ,IEAR
0004                  COMMON/DOG/ALPHA(13)
0005                  COMMON/BINS/S(13),T,DO,ALO(4,13),N(4,13)
0006                  COMMON/FF/ZAP(4),PI,TPI,Z1,X2,X3,X1,DDD(4,13),DDR(4,13),DDL(4,13)
0007                  COMMON/GOLD/DELTA,PHI1,PHI2,FP(4,13)
0008                  COMMON/BIT/XR1(3,13),XR2(3,13),H(4),DO1(4,13),DO2(4,13),
                     1DR(4,13),AC1(13),AO2(13),PC(4,13),QO(4),ZO(4),PB
0009                  DIMENSIONDD10D(4,13),DD10L(4,13),DD10R(4,13),DDDR(13),DDRR(13),
                     1DDLR(13),DD10DR(13),DD10LR(13),DD10RR(13),DDDV(4),DDRV(4),DDLV(4),
                     2DD10DV(4),DD10RV(4),DD10LV(4)
0010                  DIMENSIONPP10(4,13),PPV(4),PP10V(4),PPR(13),PP10R(13)
0011                  REALLEQ(4,13),L10(4,13),LEQR(13),L10R(13),LEQV(4),L10V(4)
0012                  REALLEQT,L10T
0013                  DIMENSIONBLEQ(4,13),BL10(4,13),BLEQR(13),BL10R(13),BLEQV(4),
                     1BL10V(4)
0014                  DIMENSIONDLEQ(4,13),DL10(4,13),DLEQV(4),DL10V(4),DLEQR(13),
                     1DL10R(13)
                C
                C INPUT
                C
0015                  TPI=2.*PI
0016                  READ(IN,1)T,EPS,THETA
0017                  WRITE(MOUT,40)T,EPS,THETA
0018            40    FORMAT('1',T33,'BASIC INPUT DATA'//T35,'OPTION DATA'//
                     1T17,'TIME INTERVAL FOR LEQ CALCULATIONS(HR)',T57,'=',F8.2/
                     2T17,'EPSILON FOR BARRIER (0=THIN,1=BERM)',T57,'=',F8.2/
                     3T17,'CRITERION FOR PARALLELISM(DEG)',T57,'=',F8.2/)
0019                  Z1=-.1916-.0635*EPS
0020                  THETA=COS(THETA*PI/180.)
0021                  IF(ABS(THETA).LE.1.E-4)THETA=0.
0022                  X2=10.**(-.5-.3*EPS)
0023                  X3=10.**(-2.-.3*EPS)
0024                  READ(IN,2)NCP
0025                  READ(IN,2)NI
0026                  READ(IN,3)(H(I),I=1,NI)
0027                  WRITE(MOUT,41)
0028            41    FORMAT('0',T23,'SOURCE HEIGHT OF VEHICLES IN METRES'/)
0029                  WRITE(MOUT,42)
0030            42    FORMAT(T24,'CARS',T33,'MEDIUM',T43,'HEAVY',T53,'OTHER'/T33,
                     1'TRUCKS',T43,'TRUCKS'/)
0031                  WRITE(MOUT,43)(H(I),I=1,NI)
0032            43    FORMAT(T21,4(F7.2,3X))
0033                  IF(NI.EQ.4)READ(IN,4)A(4),B(4)
```

MAIN PROGRAM LISTING: SNAP 1.0

```
      WRITE(MOUT,44)
   44 FORMAT('0',T18,'NOISE LEVEL-SPEED COEFFICIENTS (L0=A+B*LOG(S))'/)
      WRITE(MOUT,42)
      WRITE(MOUT,45) (A(I),I=1,NI)
   45 FORMAT(T18,'A',T21,4(F7.2,3X))
      WRITE(MOUT,46) (B(I),I=1,NI)
   46 FORMAT(T18,'B',T21,4(F7.2,3X))
      READ(IN,2)IBAR
      READ(IN,2)NJ
      DO1001J=1,NJ
      READ(IN,6)(XR1(K,J),K=1,2),(XR2(K,J),K=1,3)
      XR1(3,J)=XR2(3,J)
C
C SET UP DIFFERENCE VECTORS AND CHECK FOR PARALLELISM
C
      CALLDIFF(XR1(1,J),XR2(1,J),DR(1,J))
      ANG=ANGLE(DR(1,J),DR(1,1))
      IF(ABS(ANG).LT.THETA)CALLMESS1
      J1=J+1-IBAR
      IF(IBAR.EQ.2.AND.J.EQ.1)GOTO1001
      READ(IN,7)S(J),(N(I,J),I=1,NI)
      IF(S(J).LT.50.)WRITE(MOUT,80)J1,S(J)
   80 FORMAT('0',T14,'LANE',I3,' SPEED',F6.1,' IS LESS THAN 50',
     1' AND IS SET TO 50'/)
      IF(S(J).LT.50.)S(J)=50.
      IF(S(J).GT.100.)WRITE(MOUT,81)J1,S(J)
   81 FORMAT('0',T13,'LANE',I3,' SPEED',F6.1,' IS GREATER THAN 100',
     1' AND IS SET TO 100'/)
      IF(S(J).GT.100.)S(J)=100.
      READ(IN,3)(AA(I,J),I=1,NI)
 1001 CONTINUE
      WRITE(MOUT,60)
   60 FORMAT('0',T23,'COORDINATES FOR END POINTS (METRES)'/
     1T5,'SEGMENT TYPE',6X,'X1',8X,'Y1',9X,'Z1',7X,'X2',8X,'Y2',
     29X,'Z2'/)
      IF(IBAR.EQ.2)WRITE(MOUT,61)(XR1(K,1),K=1,3),(XR2(K,1),K=1,3)
   61 FORMAT(T5,'BARRIER',5X,6F10.2)
      DO2000J=IBAR,NJ
      J1=J+1-IBAR
      WRITE(MOUT,62)J1,(XR1(K,J),K=1,3),(XR2(K,J),K=1,3)
   62 FORMAT(T5,'LANE #',I4,2X,6F10.2)
 2000 CONTINUE
      CALLILL
      WRITE(MOUT,65)
   65 FORMAT('1',T12,'LANE #',3X,'SPEED',18X,'TRAFFIC VOLUME'/
     1T21,'(KM/H)',6X,'CARS',5X,'MEDIUM',4X,'HEAVY',6X,'OTHER'/
     2T41,'TRUCKS',4X,'TRUCKS'/)
      DO2001J=IBAR,NJ
```

MAIN PROGRAM LISTING: SNAP 1.0

```
0073            J1=J+1-IEAR
0074            WRITE(NOUT,66)J1,S(J),(N(I,J),I=1,NI)
0075      66    FORMAT(T12,I4,4X,F6.1,4X,4(I6,4X))
0076      2001  CONTINUE
0077            WRITE(NOUT,67)
0078      67    FORMAT('0',T25,'SOUND-LEVEL ADJUSTMENT PARAMETER'/T18,'LANE #',
               1T29,'CARS',T38,'MEDIUM',T48,'HEAVY',T59,'OTHER'/T38,'TRUCKS',
               2T48,'TRUCKS'/)
0079            DO2002J=IEAR,NJ
0080            J1=J+1-IEAR
0081            WRITE(NOUT,68)J1,(AA(I,J),I=1,NI)
0082      68    FORMAT(T16,I6,T26,4(F8.2,2X))
0083      2002  CONTINUE
0084      1000  CONTINUE
          C
          C OBSERVER LOOP
          C
0085            READ(IN,9,END=9999)ITITLE
0086      9     FORMAT(10A4)
0087            READ(IN,5)XO,(ALPHA(J),J=IEAR,NJ)
0088            CALLZERO(LEQ,L10,LEQR,L10R,LEQV,L10V,LEQT,L10T)
0089            CALLZERO(BLEQ,BL10,BLEQR,BL10R,BLEQV,BL10V,BLEQT,BL10T)
0090            CALLZERO(PP,PP10,PPR,PP10R,PPV,PP10V,PPT,PP10T)
0091            CALLZERO(DDD,DD10D,DDDR,DD10DR,DDDV,DD10DV,DDDT,DD10DT)
0092            CALLZERO(DDR,DD10R,DDRR,DD10RR,DDRV,DD10RV,DDRT,DD10RT)
0093            CALLZERO(DDL,DD10L,DDLR,DD10LR,DDLV,DD10LV,DDLT,DD10LT)
0094            KA=1
          C
          C SET UP ALL VECTORS AND ANGLES NECESSARY FOR THE CALCULATIONS
          C
0095            CALLSETUP
          C
          C CHECK FOR CLOSENESS OF OBSERVER TO BARRIER
          C
0096            IF(PC(4,1).LT.DC)CALLMESS3
          C
          C LEQ-L10 LOOP WITHOUT BARRIER
          C
0097            DO1002J=IEAR,NJ
0098            PHI1=AC1(J)
0099            PHI2=AC2(J)
0100            DO1002I=1,NI
0101            ELEQ=ALEQ(I,J)
0102            CALLSUM(ELEQ,LEQ,L10,LEQR,L10R,LEQV,L10V,LEQT,L10T)
0103      1002  CONTINUE
0104            CALLCONVER(LEQR,L10R,LEQV,L10V,LEQT,L10T)
0105            WRITE(NOUT,11)
0106      11    FORMAT('1',T31,'FHWA HIGHWAY TRAFFIC'/T30,'NOISE PREDICTION MODEL'
```

MAIN PROGRAM LISTING: SNAP 1.0

```
     1/T36,'(SNAP 1.0)'/)
      WRITE(MOUT,12)
12    FORMAT(T37,'TABLE 1'/)
      WRITE(MOUT,13)
13    FORMAT(T22,'SOUND LEVEL CONTRIBUTIONS AT RECEIVER'/
     1T32,'ALL LANE SEGMENTS'/)
      WRITE(MOUT,14)
14    FORMAT(T29,'(NO BARRIER ATTENUATION)'/)
      CALLTABLE(LEQ,L10,LEQB,L10B,LEQV,L10V,LEQT,L10T)
      IF(IBAR.EQ.1)GOTO1000
C
C ADD IN VEHICLE HEIGHTS FOR DIFFRACTION CALCULATION
C
      CALLADDV(XC,FC(1,1),ZO)
      X1=ANGLE(ZAE,FO(1,1))
      WRITE(MOUT,11)
      WRITE(MOUT,21)
21    FORMAT(T37,'TABLE 2'/)
      WRITE(MOUT,13)
      WRITE(MOUT,22)
22    FORMAT(T28,'(WITH BARRIER ATTENUATION)'/)
C
C LEQ-L10 LOOP WITH BARRIER
C
      DO1201I=1,NI
      DO1201J=IBAR,NJ
      CALLDIFFRA(I,J)
      PB=DDD(I,J)+DDL(I,J)+DDB(I,J)
      KA=1
      FUP=EE(I,J)
      CALLSUM(FUP,EE,PE10,EPB,EP10B,PPV,PP10V,PPT,PP10T)
      PUP=DDR(I,J)
      CALLSUM(FUP,DDR,DD10R,DDRB,DD10RB,DDRV,DD10RV,DDRT,DD10RT)
      FUP=DDL(I,J)
      CALLSUM(FUP,DDL,DD10L,DDLB,DD10LB,DDLV,DD10LV,DDLT,DD10LT)
      KA=0
      IF(PC(4,J).LE.PC(4,1))KA=1
      PAP=APT(DDD(I,J))
      PAP=PAP+DELK(PAP)
      PC=TEA(PAP)
      PUP=DDD(I,J)
      CALLSUM(FUP,DDD,DD10D,DDDB,DD10DB,DDDV,DD10DV,DDDT,DD10DT)
      PC=TEA(DD10D(I,J))+TEA(DD10L(I,J))+TPA(DD10R(I,J))
      CALLSUM(EE,BLEQ,BL10,BLEQB,BL10B,BLEQV,BL10V,BLEQT,BL10T)
1201  CONTINUE
      CALLCONVER(BLEQB,BL10B,BLEQV,BL10V,BLEQT,BL10T)
      CALLTABLE(BLEQ,BL10,BLEQB,BL10B,BLEQV,BL10V,BLEQT,BL10T)
      CALLDIFFE(BLEQ,LEQ,DLEQ)
```

MAIN PROGRAM LISTING: SNAP 1.0

```
      CALLDIFFE(BL10,L10,DL10)
      DLEQT=LEQT-BLEQT
      DL10T=L10T-BL10T
      DO1203I=1,NI
      DLEQV(I)=LEQV(I)-BLEQV(I)
      DL10V(I)=L10V(I)-BL10V(I)
 1203 CONTINUE
      DO1204J=IBAB,NJ
      DLEQR(J)=LEQR(J)-BLEQR(J)
      DL10R(J)=L10R(J)-BL10R(J)
 1204 CONTINUE
      WRITE(MOUT,11)
      WRITE(MOUT,55)
 55   FORMAT(T37,'TABLE 3'/)
      WRITE(MOUT,23)
 23   FORMAT(T27,'BARRIER FIELD INSERTION LOSS'///)
      CALLTABLE(DLEQ,DL10,DLEQR,DL10R,DLEQV,DL10V,DLEQT,DL10T)
C
C IF NOB=0, PRINT ALL TABLES
C IF NOT, THEN DO ANOTHER OBSERVER
C
      IF(NOB.NE.0)GOTO1000
      CALLCONVER(PPR,PP10R,PPV,PP10V,PPT,PP10T)
      CALLCONVER(DDDR,DD10DR,DDDV,DD10DV,DDDT,DD10DT)
      CALLCONVER(DDRR,DD10RR,DDRV,DD10RV,DDRT,DD10RT)
      CALLCONVER(DDLR,DD10LR,DDLV,DD10LV,DDLT,DD10LT)
      CALLDIFFE(DDD,PP,DLEQ)
      CALLDIFFE(DD10D,PP10,DL10)
      DLEQT=PPT-DDDT
      DL10T=PP10T-DD10DT
      DO3000I=1,NI
      DLEQV(I)=PPV(I)-DDDV(I)
      DL10V(I)=PP10V(I)-DD10DV(I)
 3000 CONTINUE
      DO3001J=IBAB,NJ
      DLEQR(J)=PPR(J)-DDDR(J)
      DL10R(J)=PP10R(J)-DD10DR(J)
 3001 CONTINUE
      WRITE(MOUT,11)
      WRITE(MOUT,70)
 70   FORMAT(T37,'TABLE 4'/)
      WRITE(MOUT,13)
      WRITE(MOUT,71)
 71   FORMAT(T24,'LANE SEGMENTS SHIELDED BY BARRIER'/T29,
     1'(NO BARRIER ATTENUATION)'/)
      CALLTABLE(PP,PP10,PPR,PP10R,PPV,PP10V,PPT,PP10T)
      WRITE(MOUT,11)
      WRITE(MOUT,30)
```

MAIN PROGRAM LISTING: SNAP 1.0

```
30    FORMAT(T37,'TABLE 5'/)
      WRITE(MOUT,13)
      WRITE(MOUT,31)
31    FORMAT(T24,'LANE SEGMENTS SHIELDED BY BARRIER'/T28,
     1'(WITH BARRIER ATTENUATION)'/)
      CALLTABLE(DDD,DD10D,DDDB,DD10DB,DDDV,DD10DV,DDDT,DD10DT)
      WRITE(MOUT,11)
      WRITE(MOUT,72)
      WRITE(MOUT,13)
      WRITE(MOUT,123)
123   FORMAT(T23,'MAXIMUM BARRIER FIELD INSERTION LOSS'///)
      CALLTABLE(DLEQ,DL10,DLEQB,DL10B,DLEQV,DL10V,DLEQT,DL10T)
72    FORMAT(T37,'TABLE 6'/)
      WRITE(MOUT,11)
      WRITE(MOUT,32)
32    FORMAT(T37,'TABLE 7'/)
      WRITE(MOUT,13)
      WRITE(MOUT,33)
33    FORMAT(T20,'UNSHIELDED LANE SEGMENTS: LEFT OF BARRIER'/)
      CALLTABLE(DDL,DD10L,DDLB,DD10LB,DDLV,DD10LV,DDLT,DD10LT)
      WRITE(MOUT,11)
      WRITE(MOUT,34)
34    FORMAT(T37,'TABLE 8'/)
      WRITE(MOUT,13)
      WRITE(MOUT,35)
35    FORMAT(T20,'UNSHIELDED LANE SEGMENTS: RIGHT OF BARRIER'/)
      CALLTABLE(DDR,DD10R,DDRB,DD10RB,DDRV,DD10RV,DDRT,DD10RT)
      GOTO1000
9999  CONTINUE
      STOP
1     FORMAT(3F6.0)
2     FORMAT(I2)
3     FORMAT(4F6.0)
4     FORMAT(2F6.0)
5     FORMAT(3F10.0,12F4.0)
6     FORMAT(5F10.0)
7     FORMAT(F6.0,4I6)
      END
```

MAIN PROGRAM LISTING: SNAP 1.0

C.4 BLOCK DATA

PURPOSE: To store constants used by the program

SUBPROGRAMS USED: None.

VARIABLES:

A(I); The constant term in the log-speed relation for the vehicle reference energy mean noise emission level
- A(1) denotes automobiles
- A(2) denotes medium trucks
- A(3) denotes heavy trucks
- A(4) denotes user defined vehicle

B(I); The coefficient of the log(S) term in the relation for the vehicle reference energy mean emission level. Subscript identical to A(I) above.

DO; The reference distance for the vehicle reference energy mean emission level. Set to 15.2 m.

DC; The criterion distance for observer closeness to a barrier. Set. to 0.5 m.

ZAP(I); The x,y,z-coordinates and length (I=1,2,3,4 respectively) of a unit vector in the z (vertical) direction

PI; $\pi = 3.1415926$

M1,M2; The alphanumeric labels: L_{eq} and L_{10}

IN,MOUT; The input/output device for read/write statements.

RESTRICTIONS: None

SIZE:

REFERENCES: None.

```
      BLOCKDATA
      CCMMON/A/I,J,M1,M2,IN,MOUT,ITITLE(10)
      CCMMON/B/A(4),B(4),DC
      CCMMON/E/S(13),T,DC,ALO(4,13),N(4,13)
      CCMMON/FF/ZAP(4),EI,TPI,Z1,X2,X3,X1,DID(4,13),DDR(4,13),DDL(4,13)
      CCMMON/G/DELTA,PHI1,PHI2,PP(4,13)
      DATAZAP/0.,0.,1.,1./
      DATAPI/3.1415926/
      DATADO/15.2/
      DATAM1,M2/'LEQ','L10'/
      DATADC/.5/,A/-2.43,16.36,38.48,0./,B/38.05,33.91,24.56,0./
      DATAIN,MOUT/5,6/
      END
```

LISTING: BLOCK DATA

MAIN PROGRAM
BLOCK DATA

SUBROUTINES

- ADDV (DOT, SQRT)*
- CONVER (APT)
- DIFF (DOT, SQRT)
- DIFFB (None)
- DIFFRA (ADDV, DIFF, ALEQ, ANGLE, DIF, DOT, SQRT
- LLL (ALOG10)
- MESS1 (None)
- MESS3 (None)
- SETUP (ADDV, DIFF, UNIT, ANGLE, ARCOS, DOT, MESS2)
- SUM (APT, DELK, TPA)
- TABLE (None)
- ZERO (None)

Secondary Level

- QATR (External Function)

FUNCTIONS

- ALEQ (ABS, AMIN1, AMAX1, ANGLE, PSI)*
- ANGLE (DOT)
- APT (ALOG10)
- DELK (ALOG10)
- TPA (None)

Secondary Level

- DOT (None)
- PSI (QATR, COSALP)
- DIF (DELTAB)
- DELTAB (QATR, F)
- COSALP (COS)
- F (ABS, COS, SQRT, TAN, TANH)

*Subprograms used are enclosed in parenthesis

FIGURE C-1. SUBPROGRAM STRUCTURE: SNAP 1.0

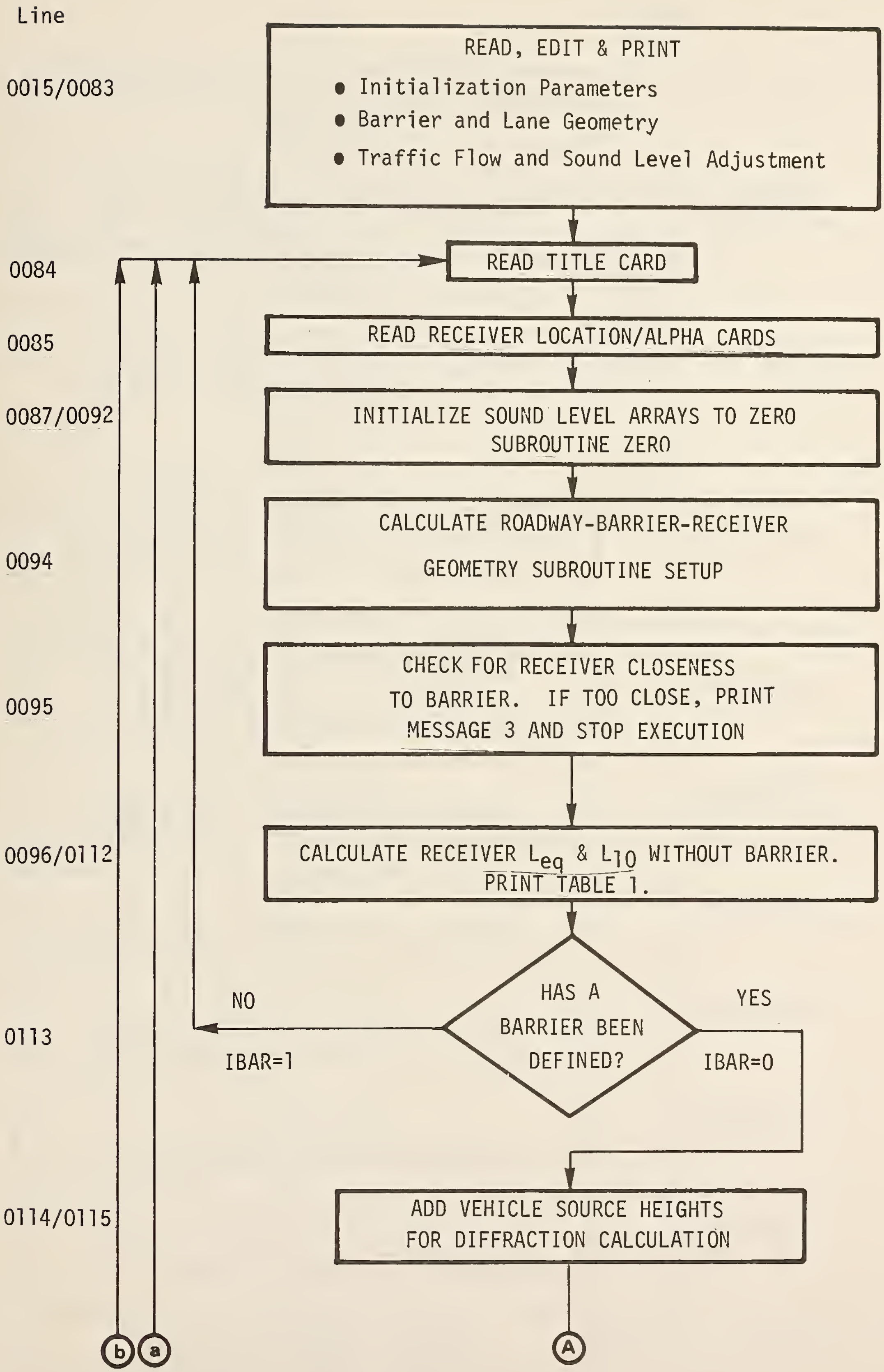

FIGURE C-2. MAIN PROGRAM FLOW DIAGRAM: SNAP 1.0

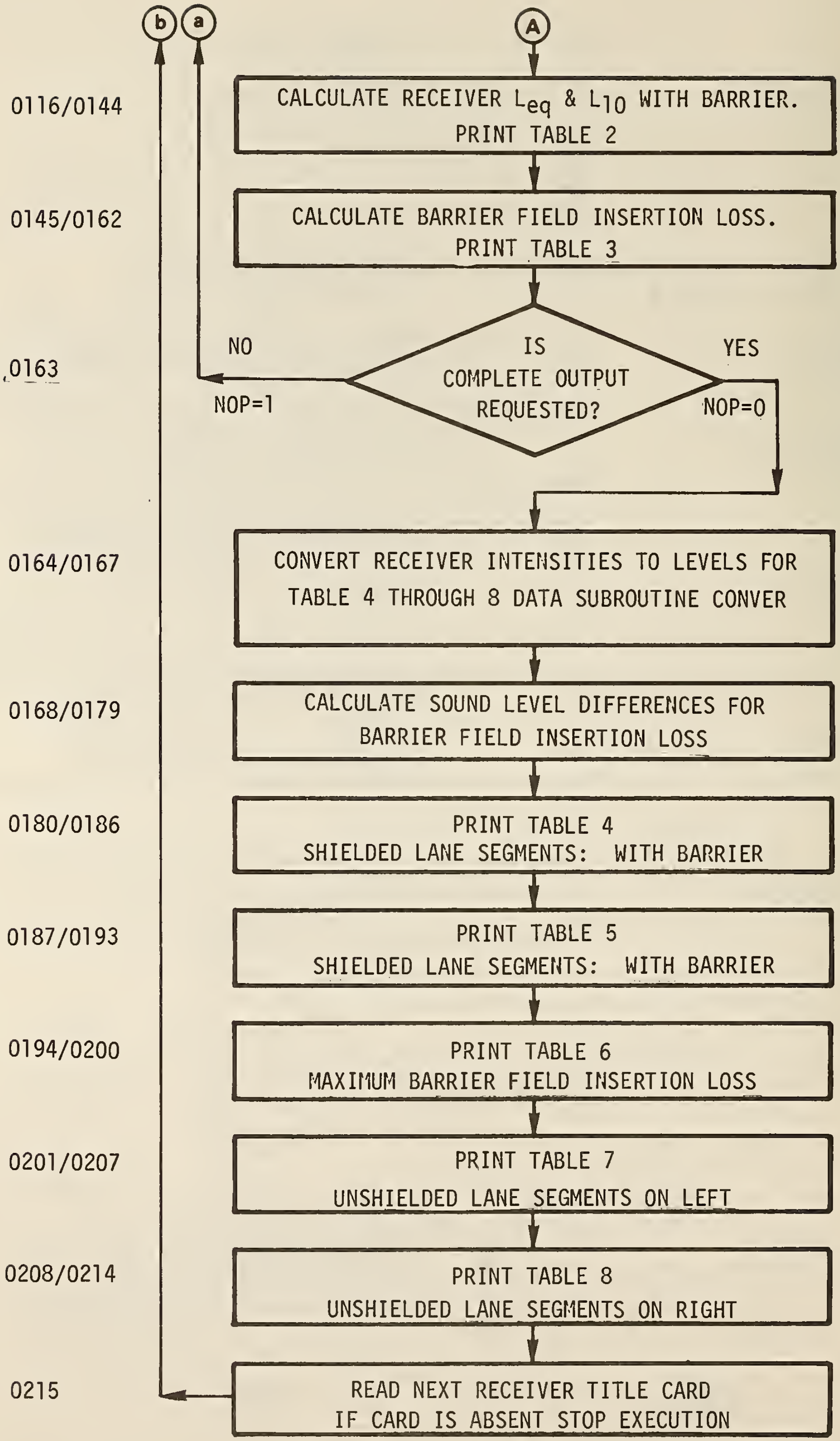

FIGURE C-2. MAIN PROGRAM PLOW DIAGRAM: SNAP 1.0

APPENDIX D
SUBPROGRAM DESCRIPTIONS

For the user's reference, this appendix describes the subprograms used by SNAP 1.0. Subroutines are listed followed by functions. Subroutines are listed in alphabetical order. Functions are listed in alphabetical order.

D.1 SUBROUTINE ADDV(A,B,C)

PURPOSE:	To add the components of two vectors (A,B) and to calculate the length, C(4), of the resultant vector (C)
SUBPROGRAMS USED:	DOT(A,B),SQRT(X)
VARIABLES:	A(I), B(I) (I=1,2,3); the components of the two vectors to be added. C(I) = A(I)+B(I); the components of the resultant vector. C(4); the length of the resultant vector.
RESTRICTIONS:	This subroutine considers three dimensional vectors as follows: I=1 x-component I=2 y-component I-3 z-component I=4 length of vector
SIZE:	462
REFERENCES:	None.

```
              SUBROUTINEADDV(A,B,C)
C
C ADD 2 3-VECTORS
C
              DIMENSIONA(4),B(4),C(4)
              DO1001I=1,3
              C(I)=A(I)+B(I)
       1001   CONTINUE
              C(4)=SQRT(DOT(C(1),C(1)))
              RETURN
              END
```

D.2 SUBROUTINE CONVER(AR,A10R,AV,A10V,AT,A10T)

PURPOSE: To convert intensity ,$10^{L/10}$, to a level, L, for accumulation arrays AR,A10R,AV,A10V and the totals AT,A10T.

SUBPROGRAMS USED: APT(X)

VARIABLES:

AR(J) - The L_{eq} contribution from roadway J

A10R(J) - The L_{10} contribution from roadway J

AV(I) - The L_{eq} contribution from vehicle type I

A10V(I) - The L_{10} contribution from the vehicle type I

AT - The total L_{eq} value of the receiver

A10T - The total L_{10} value at the receiver

RESTRICTIONS: None

SIZE: 678

REFERENCES: None

```
      SUBROUTINECONVER(AR,A10R,AV,A10V,AT,A10T)
      COMMON/C/XO(3),NI,NJ,IBAR
      DIMENSIONAV(4),A10V(4),AR(13),A10R(13)
      DO1001I=1,NI
      AV(I)=APT(AV(I))
      A10V(I)=APT(A10V(I))
 1001 CONTINUE
      DO1002J=IBAR,NJ
      AR(J)=APT(AR(J))
      A10R(J)=APT(A10R(J))
 1002 CONTINUE
      AT=APT(AT)
      A10T=APT(A10T)
      RETURN
      END
```

D.3 SUBROUTINE DIFF(A,B,C)

PURPOSE: To calculate the difference of two vectors (A,B) and to calculate the length, C(4), of the resultant vector (C).

SUBPROGRAMS USED: DOT(A,B), SQRT(X)

VARIABLES: A(I), B(I) (I=1,2,3); the components of the two input vectors
C(I)=A(I)-B(I); the components of the resultant vector.
C(4); the length of the resultant vector

RESTRICTIONS: This subroutine considers three dimensional vectors as follows:

I=1	x-component
I=2	y-component
I=3	z-component
I=4	length of vector

SIZE: 462

REFERENCES: None

```
0001                 SUBROUTINEDIFF(A,B,C)
              C
              C CALCULATE THE DIFFERENCE OF 2 3-VECTORS
              C
0002                 DIMENSIONA(4),B(4),C(4)
0003                 DO1001I=1,3
0004                 C(I)=B(I)-A(I)
0005          1001   CONTINUE
0006                 C(4)=SQRT(DOT(C(1),C(1)))
0007                 RETURN
0008                 END
```

D.4 SUBROUTINE DIFFB(A,B,C)

PURPOSE: To calculate the difference between two arrays (A,B).

SUBPROGRAMS USED: None.

VARIABLES: A(I,J), B(I,J) input arrays

C(I,J)=B(I,J)-A(I,J); the resulting difference array

RESTRICTIONS: Subscript I denotes a vehicle type

Subscript J denotes a traffic lane

Dimension statements restrict usage to a maximum of four (4) vehicle types (NI=4) and 12 traffic lanes (NJ=13)

SIZE: 514

REFERENCES: None.

```
0001                 SUBROUTINEDIFFB(A,B,C)
               C
               C SUBTRACT MATRIX A FROM B
               C
0002                 COMMON/C/XO(3),NI,NJ,IBAR
0003                 DIMENSIONA(4,13),B(4,13),C(4,13)
0004                 DO1001I=1,NI
0005                 DO1001J=IBAR,NJ
0006                 C(I,J)=B(I,J)-A(I,J)
0007           1001  CONTINUE
0008                 RETURN
0009                 END
```

D.5 SUBROUTINE DIFFRA

PURPOSE: Performs diffraction calculations. DIFFRA sorts each lane into one of six categories and determines whether a diffraction calculation needs to be performed. It then calculates the L_{eq} with or without diffraction, as the case may be, and returns to the calling program.

SUBPROGRAMS USED: ALEQ, SQRT, ADDV, DIFF, ANGLE, DIF, DOT

VARIABLES:

I	Vehicle Type
J	Lane number

Subroutine Parameters

A01(J)	"Left" angle of lane J
A02(J)	"Right" angle of lane J
PHI1	Lower Limit angle of integration
PHI2	Upper limit angle of integration
PO(K,J)	Vector normal to lane J from receiver
QO(K,J)	QO=PO(J)+H(I) Vector normal taking vehicle height into consideration
RO(K)	RO=XO+QO Coordinates of the end point of QO
SO(K)	SO=RO-ZO Vector normal from lane J to barrier
DELTA	DELTA=$\|PO\| + \|SO\| - \|QO\|$
Z2	Z2=$\cos^{-1}$ (ZAP, QO)

Output Parameters

DDD	See MAIN Program variable list
DDL	See MAIN Program variable list
DDR	See MAIN Program variable list
PP	See MAIN Program variable list
PB	$10^{L_{eq}/10}$ for vehicle I, lane J with barrier installed

RESTRICTIONS: None.

SIZE: 2172

REFERENCES: None.

```
      SUBROUTINEDIFFRA(I,J)
C
C DIVIDE LANES INTO SHIELDED AND UNSHIELDED SEGMENTS
C CALCULATE LEQ FROM EACH SEGMENT INDIVIDUALLY
C
      COMMON/C/XO(3),NI,NJ,IBAB
      COMMON/FF/ZAP(4),PI,TPI,Z1,X2,X3,X1,DDD(4,13),DDR(4,13),DDL(4,13)
      COMMON/G/DELTA,PHI1,PHI2,PP(4,13)
      COMMON/H/XB1(3,13),XB2(3,13),H(4),DO1(4,13),DO2(4,13),
     1DR(4,13),AO1(13),AO2(13),PO(4,13),QO(4),ZO(4),PB
      DIMENSIONRO(4),SO(4)
      IF(AO2(J).GT.AO1(1).AND.AO1(J).LT.AO2(1))GOTO1005
      PHI1=AO1(J)
      PHI2=AO2(J)
      PB=ALEQ(I,J)
      IF(AO2(J).LE.AO1(1))DDL(I,J)=PB
      IF(AO1(J).GE.AO2(1))DDR(I,J)=PB
      RETURN
 1005 CONTINUE
      DO1004K=1,2
      QO(K)=PO(K,J)
 1004 CONTINUE
      QO(3)=PO(3,J)+H(I)
      QO(4)=SQRT(DOT(QO(1),QO(1)))
      CALLADDV(XO,QO,RO)
      CALLDIFF(ZO,RO,SO)
      DELTA=PO(4,1)+SO(4)-QO(4)
      Z2=ANGLE(ZAP,QO)
      IF(Z2.GT.X1)DELTA=-DELTA
      IF(AO1(J).LE.AO1(1).AND.AO2(J).GE.AO2(1))GOTO1001
      IF(AO2(J).LE.AO2(1).AND.AO1(J).GT.AO1(1))GOTO1002
      IF(AO1(J).LT.AO1(1))GOTO1003
      PHI1=AO1(J)
      PHI2=AO2(1)
      PP(I,J)=ALEQ(I,J)
      PB=DIF(I,J)
      IF(PO(4,J).LE.PO(4,1))PB=PP(I,J)
      DDL(I,J)=PB
      PHI1=AO2(1)
      PHI2=AO2(J)
      DDR(I,J)=ALEQ(I,J)
      RETURN
 1001 CONTINUE
      PHI1=AO1(1)
      PHI2=AO2(1)
      PP(I,J)=ALEQ(I,J)
      PB=DIF(I,J)
      IF(PO(4,J).LE.PO(4,1))PB=PP(I,J)
```

```
      DDD(1,J)=PB
      PHI1=AO1(J)
      PHI2=AO1(1)
      DDL(1,J)=ALEQ(I,J)
      PHI1=AO2(1)
      PHI2=AO2(J)
      DDR(I,J)=ALEQ(I,J)
      RETURN
 1002 CONTINUE
      PHI1=AO1(J)
      PHI2=AO2(J)
      PP(I,J)=ALEQ(I,J)
      PB=DIF(I,J)
      IF(PO(4,J).LE.PO(4,1))PB=PP(I,J)
      DDD(I,J)=PB
      RETURN
 1003 CONTINUE
      PHI1=AO1(1)
      PHI2=AO2(J)
      PP(I,J)=ALEQ(I,J)
      PB=DIF(I,J)
      IF(PO(4,J).LE.PO(4,1))PB=PP(I,J)
      DDD(I,J)=PB
      PHI1=AO1(J)
      PHI2=AO1(1)
      DDL(I,J)=ALEQ(I,J)
      PB=PB+DDL(I,J)
      RETURN
      END
```

D.6 SUBROUTINE: LLL

PURPOSE: To calculate the vehicle reference energy mean emission level, L_0, as a function of travel speed on a traffic lane and constant sound level adjustments.

SUBPROGRAMS USED: ALOG10(X)

VARIABLES:
Subscript J denotes a travel lane
Subscript I denotes a vehicle type
A(I), the constant term in the vehicle sound level function for vehicle type I
B(I), the coefficient of the log-speed term in the vehicle sound level function for vehicle type I
ALO(I), the vehicle reference energy mean emission level, dB, for vehicle type I
S(J), the average travel speed on the Jth travel lane
AA (I,J), the constant sound level adjustment

RESTRICTIONS: The subroutine considers a relationship between the reference sound level and the vehicle speed, S, in the form L_0 = A+Blog(S)
The appropriate units depend upon the numerical values for A and B. Metric units are used (i.e., S is expressed in km/h).

SIZE: 470

REFERENCES: None

```
            SUBROUTINELLL
      C
      C CALCULATE LO
      C
            COMMON/BETA/A(4),B(4),DC,AA(4,13)
            COMMON/CAT/XO(3),NI,NJ,IBAR
            COMMON/EINS/S(13),T,DO,ALO(4,13),N(4,13)
            DO1001J=IBAR,NJ
            X=ALOG10(S(J))
            DO1001I=1,NI
            ALO(I,J)=A(I)+B(I)*X+AA(I,J)
       1001 CONTINUE
            RETURN
            END
```

D.7 SUBROUTINE MESS1

PURPOSE: To print the error message:
"LANE X IS NOT PARALLEL"
and to terminate execution

SUBPROGRAMS USED: None

VARIABLES: J, the traffic lane number

RESTRICTIONS: Once the message is printed, the execution of the program is terminated.

SIZE: 358

REFERENCES: None

```
0001              SUBROUTINE MESS1
            C
            C IF LANES ARE NOT PARALLEL, STOP
            C
0002              COMMON/A/I,J,M1,M2,IN,MOUT,ITITLE(10)
0003              COMMON/C/XO(3),NI,NJ,IBAR
0004              J2=J+1-IBAR
0005              WRITE(MOUT,1)J2
0006        1     FORMAT('OLANE',I3,' IS NOT PARALLEL'/)
0007              STOP
0008              END
```

D.8 SUBROUTINE MESS 2

PURPOSE: To print the error message:
"LANE X IS TOO CLOSE"
and to terminate execution

SUBPROGRAMS USED: None

VARIABLES: J, the traffic lane number

RESTRICTIONS: Once the message is printed, the execution of the program is terminated.

SIZE: 358

REFERENCES: None

```
      SUBROUTINEMESS2
C
C IF LANE IS TOO CLOSE TO OBSERVER, STOP
C
      COMMON/A/I,J,M1,M2,IN,MOUT,ITITLE(10)
      COMMON/C/XO(3),NI,NJ,IBAR
      J2=J+1-IBAR
      WRITE(MOUT,1) J2
1     FORMAT('OLANE',I3,' IS TOO CLOSE'/)
      STOP
      END
```

D.9 SUBROUTINE MESS3

PURPOSE: To print the error message:
"OBSERVER TOO CLOSE TO BARRIER"
and to terminate execution

SUBPROGRAMS USED: None

RESTRICTIONS: Once the message is printed, the execution of the program is terminated

SIZE: 322

REFERENCES: None.

```
                    SUBROUTINEMESS3
      C
      C IF OBSERVER IS TOO CLOSE TO BARRIER, STOP
      C
                    COMMON/A/I,J,M1,M2,IN,MOUT,ITITLE(10)
                    WRITE(MOUT,1)
      1             FORMAT('0OBSERVER TOO CLOSE TO BARRIER'/)
                    STOP
                    END
```

D.10 SUBROUTINE QATR(XL,XU,EPS,NDIM,FCT,Y,IERR,AUX)

PURPOSE: To numerically evaluate the integral:

$$Y = \int_{XL}^{XU} FCT(x)dX$$

SUBPROGRAMS USED: External Function subprogram, FCT, defined by user.

VARIABLES: See Listing.

RESTRICTIONS: The argument x should not be destroyed.

SIZE: 1222

REFERENCES: Anon.; "System/360 Scientific Subroutine Package (360A-CM-03X) Version II, Programmer's Manual", H20-0205-1 (2nd Ed.), International Business Machines Corporation, 1967.

```
C          SUBROUTINE QATR
C
C          PURPOSE
C             TO COMPUTE AN APPROXIMATION FOR INTEGRAL(FCT(X), SUMMED
C             OVER X FROM XL TO XU).
C
C          USAGE
C             CALL QATR (XL,XU,EPS,NDIM,FCT,Y,IER,AUX)
C             PARAMETER FCT REQUIRES AN EXTERNAL STATEMENT.
C
C          DESCRIPTION OF PARAMETERS
C             XL     - THE LOWER BOUND OF THE INTERVAL.
C             XU     - THE UPPER BOUND OF THE INTERVAL.
C             EPS    - THE UPPER BOUND OF THE ABSOLUTE ERROR.
C             NDIM   - THE DIMENSION OF THE AUXILIARY STORAGE ARRAY AUX.
C                      NDIM-1 IS THE MAXIMAL NUMBER OF BISECTIONS OF
C                      THE INTERVAL (XL,XU).
C             FCT    - THE NAME OF THE EXTERNAL FUNCTION SUBPROGRAM USED.
C             Y      - THE RESULTING APPROXIMATION FOR THE INTEGRAL VALUE.
C             IER    - A RESULTING ERROR PARAMETER.
C             AUX    - AN AUXILIARY STORAGE ARRAY WITH DIMENSION NDIM.
C
C          REMARKS
C             ERROR PARAMETER IER IS CODED IN THE FOLLOWING FORM
C             IER=0  - IT WAS POSSIBLE TO REACH THE REQUIRED ACCURACY.
C                      NO ERROR.
C             IER=1  - IT IS IMPOSSIBLE TO REACH THE REQUIRED ACCURACY
C                      BECAUSE OF ROUNDING ERRORS.
C             IER=2  - IT WAS IMPOSSIBLE TO CHECK ACCURACY BECAUSE NDIM
C                      IS LESS THAN 5, OR THE REQUIRED ACCURACY COULD NOT
C                      BE REACHED WITHIN NDIM-1 STEPS. NDIM SHOULD BE
C                      INCREASED.
C
C          SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C             THE EXTERNAL FUNCTION SUBPROGRAM FCT(X) MUST BE CODED BY
C             THE USER. ITS ARGUMENT X SHOULD NOT BE DESTROYED.
C
C          METHOD
C             EVALUATION OF Y IS DONE BY MEANS OF TRAPEZOIDAL RULE IN
C             CONNECTION WITH ROMBERGS PRINCIPLE. ON RETURN Y CONTAINS
C             THE BEST POSSIBLE APPROXIMATION OF THE INTEGRAL VALUE AND
C             VECTOR AUX THE UPWARD DIAGONAL OF ROMBERG SCHEME.
C             COMPONENTS AUX(I) (I=1,2,...,IEND, WITH IEND LESS THAN OR
C             EQUAL TO NDIM) BECOME APPROXIMATIONS TO INTEGRAL VALUE WITH
C             DECREASING ACCURACY BY MULTIPLICATION WITH (XU-XL).
```

```
C           FOR REFERENCE, SEE
C           (1) FILIPPI, DAS VERFAHREN VON ROMBERG-STIEFEL-BAUER ALS
C               SPEZIALFALL DES ALLGEMEINEN PRINZIPS VON RICHARDSON,
C               MATHEMATIK-TECHNIK-WIRTSCHAFT, VOL.11, ISS.2 (1964),
C               PP.49-54.
C           (2) BAUER, ALGORITHM 60, CACM, VOL.4, ISS.6 (1961), PP.255.
C
C     ..............................................................
C
      SUBROUTINE QATR(XL,XU,EPS,NDIM,FCT,Y,IER,AUX)
C
C
      DIMENSION AUX(1)
C
C     PREPARATIONS OF ROMBERG-LOOP
      AUX(1)=.5*(FCT(XL)+FCT(XU))
      H=XU-XL
      IF(NDIM-1)8,8,1
    1 IF(H)2,10,2
C
C     NDIM IS GREATER THAN 1 AND H IS NOT EQUAL TO 0.
    2 HH=H
      E=EPS/ABS(H)
      DELT2=0.
      P=1.
      JJ=1
      DO 7 I=2,NDIM
      Y=AUX(1)
      DELT1=DELT2
      HD=HH
      HH=.5*HH
      P=.5*P
      X=XL+HH
      SM=0.
      DO 3 J=1,JJ
      SM=SM+FCT(X)
    3 X=X+HD
      AUX(I)=.5*AUX(I-1)+P*SM
C     A NEW APPROXIMATION OF INTEGRAL VALUE IS COMPUTED BY MEANS OF
C     TRAPEZOIDAL RULE.
C
C     START OF ROMBERGS EXTRAPOLATION METHOD.
      Q=1.
      JI=I-1
      DO 4 J=1,JI
      II=I-J
      Q=Q+Q
      Q=Q+Q
    4 AUX(II)=AUX(II+1)+(AUX(II+1)-AUX(II))/(Q-1.)
C     END OF ROMBERG-STEP
C
      DELT2=ABS(Y-AUX(1))
      IF(I-5)7,5,5
    5 IF(DELT2-E)10,10,6
    6 IF(DELT2-DELT1)7,11,11
    7 JJ=JJ+JJ
    8 IER=2
    9 Y=H*AUX(1)
      RETURN
   10 IER=0
      GO TO 9
   11 IER=1
      Y=H*Y
      RETURN
      END
```

D.11 SUBROUTINE SETUP

PURPOSE: To calculate the geometrical parameters describing an orientation of a lane segment relative to a receiver. See Figure D- 1.

SUBPROGRAMS USED: DIFF(A,B,C), UNIT(A,B), DOT(A,B), ADDV(A,B,C), ARCOS(X,Y) ANGLE(X,Y), MESS2

VARIABLES:

XO(I), coordinates of vector locating receiver.

XR1(I,J), coordinates of vector locating end point "1" of the lane segment J.

XR2(I,J), coordinates of vector locating end point "2" of the lane segment J.

DR(I,J), the vector defining the lane segment J.

DO1(I,J), the vector defining the location of XR1 relative to XO.

DO2(I,J), the vector defining the location of XR2 relative to XO.

UR(I,J), the unit vector in the direction of DR(I,J)

PO(I,J), the vector perpendicular to lane segment J from the receiver at XO.

ZIT(I), the vector from end point 1 of the lane segment J to the intersection point of the vectors PO(K,J) and DR(I,J)

AO1(J), the angle between the normal from the receiver to the lane segment and the line from the receiver to end point "1" of the lane segment.

AO2(J), the angle between the normal from the receiver to the lane segment and the line from the receiver to end point "2" of the lane segment.

I = 1 dentoes a x-coordinate of the vector

I = 2 denotes a y-coordinate of the vector

I = 3 denotes a z-coordiante of the vector

I = 4 denotes the length of the vector

D.11 SUBROUTINE SETUP (Continued)

RESTRICTIONS: None.

SIZE: 1176

REFERENCES: See Figure D- 1.

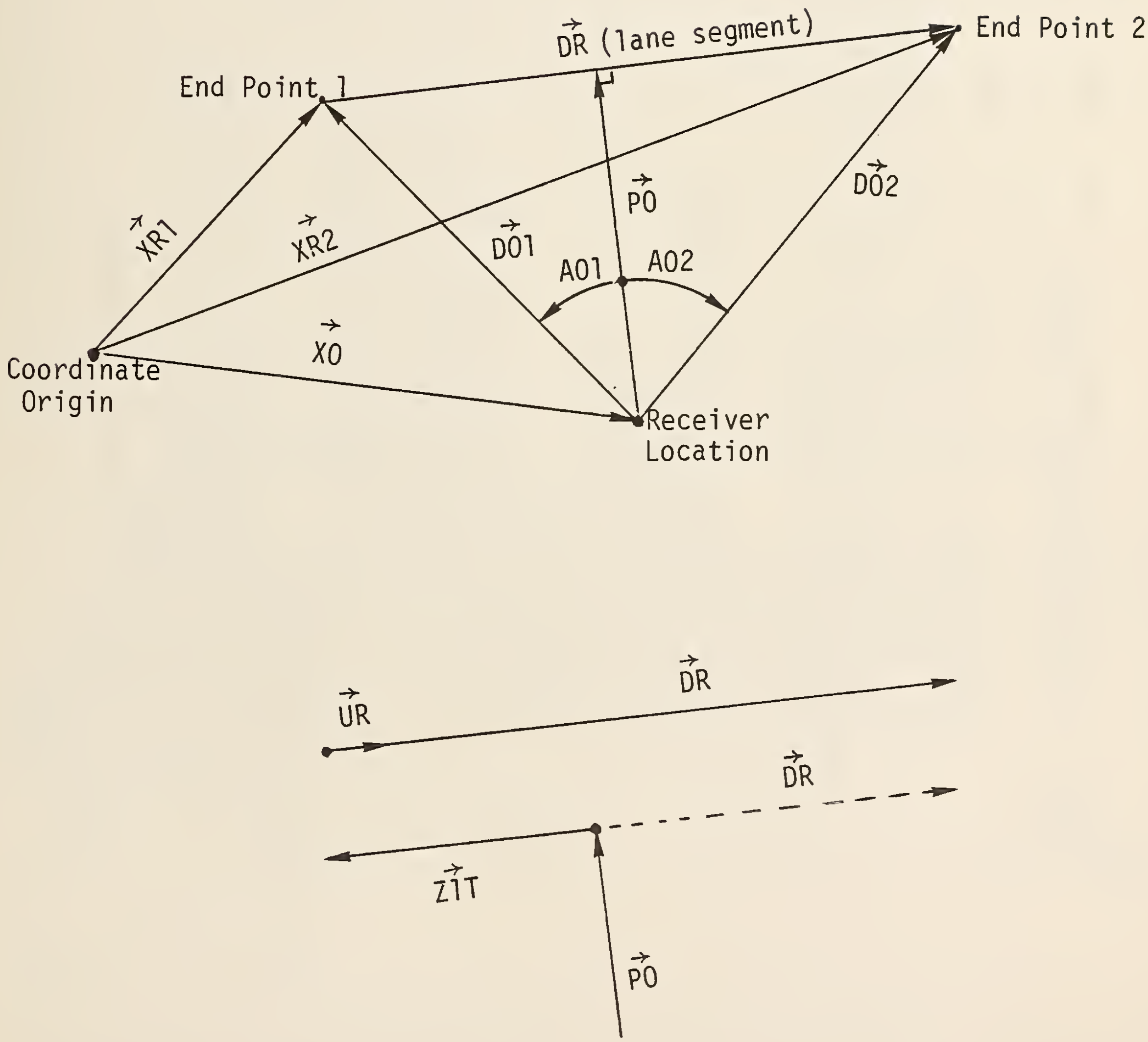

FIGURE D-1. VECTORS DEFINING GEOMETRY OF SITE

```
      SUBROUTINESETUP
C
C SET UP VECTORS FROM OBSERVER TO END POINTS AND CALCULATE
C THE ANGLES BETWEEN THE VECTORS
C
      COMMON/A/I,J,M1,M2,IN,MCUT,ITITLE(10)
      COMMON/C/XO(3),NI,NJ,IBAR
      COMMON/E/S(13),T,DC,ALO(4,13),N(4,13)
      COMMON/FF/ZAP(4),PI,TPI,Z1,X2,X3,X1,DDD(4,13),DDR(4,13),DDL(4,13)
      COMMON/H/XR1(3,13),XR2(3,13),H(4),DO1(4,13),DO2(4,13),
     1DR(4,13),AO1(13),AO2(13),PO(4,13),OC(4),ZO(4),PB
      DIMENSIONZIT(3),UR(4)
      PI2=PI/2.
      DO1003J=1,NJ
      CALLDIFF(XO,XR1(1,J),DO1(1,J))
      CALLDIFF(XO,XR2(1,J),DO2(1,J))
      CALLUNIT(DR(1,J),UR)
      Y=-DOT(UR(1),DO1(1,J))
      DO1002K=1,3
      ZIT(K)=Y*UR(K)
 1002 CONTINUE
      CALLADDV(ZIT,DO1(1,J),PC(1,J))
      IF(IBAR.EQ.2.AND.J.EQ.1)GOTO1001
      IF(PO(4,J).GE.DO)GOTO1001
      O1=ARCOS(-ANGLE(DR(1,J),DO1(1,J)))
      O2=ARCOS(ANGLE(DR(1,J),DO2(1,J)))
      IF(O1.GE.PI2.OR.O2.GE.PI2)GOTO1001
      CALLMESS2
 1001 CONTINUE
      AO1(J)=ARCOS(ANGLE(PO(1,J),DO1(1,J)))
      AO2(J)=ARCOS(ANGLE(PO(1,J),DO2(1,J)))
      IF(Y.LE.0.)GOTO1003
      AO1(J)=-AO1(J)
      IF(Y.GT.DR(4,J))AO2(J)=-AO2(J)
 1003 CONTINUE
      RETURN
      END
```

D.12 SUBROUTINE SUM(P,AEQ,A10,AR,A10R,AV,A10V,AT,A10T)

PURPOSE:	To sum, on an intensity basis, the sound levels at a receiver due to a single vehicle type operating on a single lane segment.
SUBPROGRAMS USED:	APT(X), DELK(X), TPA(X)

VARIABLES:

P;	the acoustic intensity to be added to the accumulation arrays.
AEQ(I,J);	the equivalent sound level at the receiver from vehicle type I on lane J.
A10(I,J);	the L_{10} sound level at the receiver from vehicle type I on lane J.
AR(J);	the equivalent sound level intensity at the receiver from lane J.
A10R(J);	the L_{10} sound level intensity at the receiver from lane J.
AV(I);	the equivalent sound level intensity at the the receiver from vehicle type I.
A10V(I);	the L_{10} sound level intensity at the receiver from vehicle type I.
AT;	the total L_{eq} sound level intensity at the receiver
A10T;	the total L_{10} sound level intensity at the receiver
P10;	the L_{10} sound level intensity at the receiver from vehicle type I on lane J.

RESTRICTIONS: The summation is accomplished external to the subprogram. That is, the accumulation is based upon the entry value of the argument, P, and the values of I and J specified by COMMON/A/.

SIZE: 820

REFERENCES: None.

```
0001                 SUBROUTINESUM(P,AEQ,A10,AR,A10R,AV,A10V,AT,A10T)
           C
           C ACCUMULATE LEQ, L10 OVER LANES AND VEHICLES
           C
0002                 COMMON/A/I,J,M1,M2,IN,MOUT,ITITLE(10)
0003                 COMMON/C/XO(3),NI,NJ,IBAR
0004                 DIMENSIONAEQ(4,13),A10(4,13),AR(13),A10R(13),AV(4),A10V(4)
0005                 AEQ(I,J)=APT(P)
0006                 A10(I,J)=AEQ(I,J)+DELK(AEQ(I,J))
0007                 P10=TPA(A10(I,J))
0008                 AR(J)=AR(J)+P
0009                 A10R(J)=A10R(J)+P10
0010                 AV(I)=AV(I)+P
0011                 A10V(I)=A10V(I)+P10
0012                 AT=AT+P
0013                 A10T=A10T+P10
0014                 RETURN
0015                 END
```

D.13 SUBROUTINE TABLE(AEQ,A10,AR,A10R,AV,A10V,AT,A10T)

PURPOSE: To print heading and sound level metrics by vehicle type (columns) and, lane number (rows) for prediction output.

SUBPROGRAMS USED: None

VARIABLES: Subscript I denotes a vehicle type

Subscript J denotes a lane

AEQ(I,J);	L_{eq} contribution at receiver for vehicle type I on lane J.
A10(I,J);	L_{10} contribution at receiver for vehicle type I on lane J.
AR(J);	L_{eq} contribution at receiver for traffic flow on lane J.
A10R(J);	L_{10} contribution at receiver for traffic flow on lane J.
AV(I);	L_{eq} contribution at receiver for vehicle type I.
AT;	Total L_{eq} at receiver.
A10V(I);	L_{10} contribution at receiver for vehicle type I.
A10T;	Total L_{eq} at receiver.

RESTRICTIONS: The tabular format assumes four vehicle types (columns).

SIZE: 1568

REFERENCES: None

```
C
C PRINT TABLE
C
      SUBROUTINETABLE(AEQ,A10,AR,A10R,AV,A10V,AT,A10T)
      COMMON/A/PC,I,J,M1,M2,IN,MOUT,ITITLE(10),KA
      COMMON/C/XO(3),NI,NJ,IBAR
      COMMON/D/ALPHA(13)
      DIMENSIONAEQ(4,13),A10(4,13),AR(13),A10R(13),AV(4),A10V(4)
      WRITE(MOUT,98)ITITLE
98    FORMAT('0',T9,10A4/)
      WRITE(MOUT,63)
63    FORMAT('0',13X,'OBSERVER COORDINATES (METRES)'/T18,'X',
     1T28,'Y',T38,'Z'/)
      WRITE(MOUT,64)XO
64    FORMAT(1X,T11,3F10.2/)
      WRITE(MOUT,15)
15    FORMAT(1X,'LANE',T9,'ALPHA',T15,'SOUND LEVEL',T28,'AUTOS',T34,
     1'MEDIUM',T41,'HEAVY',T48,'OTHER',T55,'LANE'/
     21X,'NUMBER',T18,'METRIC',T34,'TRUCKS',T41,'TRUCKS',T55,'TOTALS'/)
      DO1200J=IBAR,NJ
      J1=J+1-IBAR
      WRITE(MOUT,16)J1,ALPHA(J),M1,(AEQ(I,J),I=1,NI)
16    FORMAT(1X,I4,T9,F5.2,T19,A3,T28,F5.2,2X,F5.2,1X,F5.2,2X,F5.2)
      WRITE(MOUT,17)AR(J)
17    FORMAT('+',T56,F5.2)
      WRITE(MOUT,18)M2,(A10(I,J),I=1,NI)
18    FORMAT(1X,T19,A3,T28,F5.2,2X,F5.2,1X,F5.2,2X,F5.2)
      WRITE(MOUT,17)A10R(J)
1200  CONTINUE
      WRITE(MOUT,19)M1,(AV(I),I=1,NI)
19    FORMAT(1X,'VEHICLE',T19,A3,T28,F5.2,2X,F5.2,1X,F5.2,2X,F5.2)
      WRITE(MOUT,17)AT
      WRITE(MOUT,20)M2,(A10V(I),I=1,NI)
20    FORMAT(1X,'TOTALS',T19,A3,T28,F5.2,2X,F5.2,1X,F5.2,2X,F5.2)
      WRITE(MOUT,17)A10T
      RETURN
      END
```

D.14 SUBROUTINE: UNIT(A,U)

PURPOSE: To calculate the unit vector, U, of a given vector, A.

SUBPROGRAMS USED: None

VARIABLES:

A(I)(I=1,2,3);	the components of the vector A.
A(4);	the length of the vector A.
U(I)=A(I)/A(4);	the components of the unit vector U.

RESTRICTIONS: The subprogram does not check to see if the vector A has zero length. Hence a division by zero is possible.

The subprogram does not assign U(4)≡ 1.0.

Usage of this subprogram recognizes these restrictions.

SIZE: 366

REFERENCES: None.

```
            SUBROUTINEUNIT(A,U)
      C
      C GENERATE THE UNIT VECTOR FROM ANY GIVEN VECTOR
      C
            DIMENSIONA(4),U(4)
            DO1001I=1,4
            U(I)=A(I)/A(4)
       1001 CONTINUE
            RETURN
            END
```

D.15 SUBROUTINE ZERO(AEQ,A10,AR,A10R,AV,A10V,AT,A10T)

PURPOSE: To set to zero all values of the accumulation arrays used to store sound level estimates.

SUBPROGRAMS USED: None

VARIABLES:

Subscript I denotes vehicle type

Subscript J denotes lane number

AEQ(I,J);	L_{eq} contribution at receiver from vehicle type I from lane J
A10(I,J);	L_{10} contribution at receiver from vehicle type I from lane J
AR(J);	L_{eq} contribution at receiver from lane J
A10(J);	L_{10} contribution at receiver from lane J
AV(I);	L_{eq} contribution at receiver from vehicle type I
A10V(I);	L_{10} contribution at receiver from vehicle type I
AT;	Total L_{eq} at receiver
A10T;	Total L_{10} at receiver

RESTRICTIONS: None

SIZE: 718

REFERENCES: None

```
      SUBROUTINEZERO(AEQ,A10,AR,A10R,AV,A10V,AT,A10T)
C
C ZERO ALL ACCUMULATION ARRAYS
C
      COMMON/C/XO(3),NI,NJ,IBAR
      DIMENSIONAEQ(4,13),A10(4,13),AR(13),A10R(13),AV(4),A10V(4)
      AT=0.
      A10T=0.
      DO1001I=1,NI
      AV(I)=0.
      A10V(I)=0.
      DO1001J=1,NJ
      AEQ(I,J)=0.
      A10(I,J)=0.
      AR(J)=0.
      A10R(J)=0.
 1001 CONTINUE
      RETURN
      END
```

D.16 FUNCTION ALEQ(I,J)

PURPOSE: To calculate the equivalent sound level of the receiver from a finite lane segment <u>not</u> shielded by a barrier.

SUBPROGRAMS USED: ABS(X), AMIN1(X,Y), AMAX1(X,Y), PSI(J,PHI1,PHI2), ANGLE(X,Y)

VARIABLES:

ALPHA(J);	The excess distance attenuation parameter for lane J to the receiver.
ALO(I,J);	The reference energy mean emission level for vehicle type I and lane J.
N(I,J);	The number of vehicles of type I on lane J during the time T.
DO;	15.2 meters (BLOCK DATA)
T;	The specified time period, in hours, for which L_{eq} is to be calculated.
S(J);	The average traffic speed in kilometers per hour for the Jth lane during the time T.
PO(4,J);	The distance in meters that the receiver is located from the Jth roadway.
DO1(4,J)	
DO2(4,J);	The distance between the receiver and the endpoints of the finite lane segment.
DR(1,J);	The vector defining the orientation and the length of the Jth lane.
THETA;	Criterion for parallelism of barrier and lane segments. See Section 5-1.
ALEQ;	The acoustic intensity at the receiver.

RESTRICTIONS: The use of this subprogram assumes that the finite lane segment is not shielded from the receiver by a barrier.

SIZE: 922

REFERENCES: See Appendix A.

```
0001            FUNCTIONALEQ(I,J)
          C
          C CALCULATE LEQ
          C
0002            COMMON/D/ALPHA(13)
0003            COMMON/E/S(13),T,DO,ALO(4,13),N(4,13)
0004            COMMON/G/DELTA,PHI1,PHI2,PP(4,13)
0005            COMMON/H/XR1(3,13),XR2(3,13),H(4),DC1(4,13),DO2(4,13),
               1DR(4,13),AO1(13),AC2(13),PO(4,13),CC(4),ZC(4),PB
0006            DATAONE/.01745329/
0007            ALP=1.+ALPHA(J)
0008            A1=10.**(ALO(I,J)/10.)
0009            A2=N(I,J)*DO/T/S(J)/1000.
0010            A3=(DO/PO(4,J))**ALP*PSI(J,PHI1,PHI2)
0011            IF(ABS(AO2(J)-AO1(J)).LE.ONE)A3=DO**ALP/ALP*(1./AMIN1(DO1(4,J),
               1DO2(4,J))**ALP-1./AMAX1(DO1(4,J),DC2(4,J))**ALP)
0012            ALEQ=A1*A2*A3
0013            RETURN
0014            END
```

D.17 FUNCTION ANGLE(A,B)

PURPOSE: To calculate the cosine of the angle between two vectors (A,B)

SUBPROGRAMS USED: DOT(A,B)

VARIABLES:

A(I), B(I) (I=1,2,3);	two three dimensional vectors
A(4);	The length of vector A
B(4);	The length of vector B

RESTRICTIONS: The subprogram does not check to see that the length of either vector A or vector B is zero. The usage of this subprogram should recognize this to prevent division by zero.

SIZE: 356

REFERENCES: None.

```
      FUNCTIONANGLE(A,B)
C
C CALCULATE THE COSINE BETWEEN 2 3-VECTORS
C
      DIMENSIONA(4),B(4)
      ANGLE=DOT(A(1),B(1))/A(4)/B(4)
      RETURN
      END
```

D.18 FUNCTION APT(X)

PURPOSE: To transorm an intensity ($10^{L/10}$) to a level (L)

SUBPROGRAMS USED: ALOG10(X)

VARIABLES: X; the input argument ($10^{L/10}$)

APT = 10log(X); the output value (L)

RESTRICTIONS: None.

SIZE: 362

REFERENCES: None.

```
FUNCTIONAPT(X)
IF(X.EQ.0.)APT=0.
IF(X.EQ.0.)RETURN
APT=10.*ALOG10(X)
RETURN
END
```

D.19 FUNCTION COSALP(X)

PURPOSE: To calculate the function: $[\cos(x)]^{\alpha}$

SUBPROGRAMS USED: COS(X)

VARIABLES:

X;	an angle, expressed in radians, locating a point on the Jth lane relative to the distance from the receiver to the Jth lane.
ALPHA(J);	the value of α for the Jth lane relative to the receiver.

RESTRICTIONS: None.

SIZE: 380

REFERENCES: See Appendix A.

```
      FUNCTIONCOSAIP(X)
      CCMMON/A/I,J,M1,M2,IN,MOUT,ITITLE(10)
      CCMMON/D/ALPHA(13)
      CCSALP=COS(X)**ALEEA(J)
      RETURN
      END
```

D.20 FUNCTION DELK(X)

PURPOSE: To calculate the difference, DELK(X), between a L_{10} estimate and an L_{eq}, X, estimate for highway traffic noise sources.

SUBPROGRAMS USED: ALOG(10)

VARIABLES:

- X; the input value of L_{eq} (dummy)
- N(I,J); the number of type I vehicles on the Jth traffic lane for the time period T
- PO(4,J); the distance between the receiver and the Jth lane
- S(J); the average travel speed for the Jth lane during the time period T
- T; the implied time period in hours.
- DELK = L_{10}-L_{eq} for the time period, T.

RESTRICTIONS: See Derivation in Appendix A-3.

SIZE: 926

REFERENCES: See Appendix A.

```
      FUNCTIONDELK(X)
C
C CONVERT LEQ TO L10
C
      COMMON/APPLE/PC,I,J,M1,M2,IN,MCUT,ITITLE(10),KA
      COMMON/DOG/ALPHA(13)
      COMMON/EINS/S(13),T,DC,ALO(4,13),N(4,13)
      COMMON/HIT/XR1(3,13),XR2(3,13),H(4),DC1(4,13),DO2(4,13),
     1DR(4,13),AO1(13),AC2(13),PO(4,13),QC(4),ZC(4),PB
      IF(X.EQ.0.)DELK=0.
      IF(X.EQ.0.)RETURN
      A=N(I,J)*PO(4,J)/S(J)/T
      IF(A.EQ.0.)DELK=0.
      IF(A.EQ.0.)RETURN
      IF(ALPHA(J).EQ.0..OR.KA.EQ.0)GOTO1001
      IF(A.LE.12.825)DELK=-16.28+14.6924*ALOG10(A)
      C=A/12.825
      IF(A.GT.12.825)DELK=14.6924*ALOG10(C)/C**.589241
      RETURN
 1001 CONTINUE
      IF(A.LE.8.11)DELK=-8.98+9.87876*ALOG10(A)
      C=A/8.11
      IF(A.GT.8.11)DELK=9.87876*ALOG10(C)/C**.46395
      RETURN
      END
```

D.21 FUNCTION DELTAB(PHI1,PHI2)

PURPOSE: To calculate the integral:

$$\Delta_B = \int_{Y_1}^{Y_2} F(Y)dY$$

for diffraction calculations.

SUBPROGRAMS USED: External Function F, Subroutine QATR.

VARIABLES:

PHI1, PHI2;	integration limits for angular orientation of shielded lane segment
AUX(10);	auxiliary array used by QATR
F;	See FUNCTION F.

RESTRICTIONS: The use of this subprogram assumes that PHI1≤PHI2.

SIZE: 404

REFERENCES: See Appendix A.2.

```
0001    FUNCTIONDELTAE(PHI1,PHI2)
0002    DIMENSIONAUX(10)
0003    EXTERNALF
0004    CALLQATR(PHI1,PHI2,1.E-4,10,F,DELTAE,IER,AUX)
0005    RETURN
0006    END
```

D.22 FUNCTION DIF(I,J)

PURPOSE: To calculate the intensity estimate. $10^{L_{eq}/10}$, at the receiver from a lane segment shielded by a barrier.

SUBPROGRAMS USED: DELTAB(PHI1,PHI2)

VARIABLES:

Subscript I denotes vehicle type

Subscript J denotes lane

ALO(I,J);	reference energy mean emission level for vehicle type I on lane J.
N(I,J);	the number of vehicles of type I on lane J comprising the traffic flow during the time period T.
DO;	15.2 meters (BLOCK DATA)
T;	time period in hours for which the traffic conditions and resulting sound level estimates apply.
S(J);	the average traffic speed for the Jth lane during the time period T.
QO(4);	

$DIF = 10^{L_{eq}/10}$

RESTRICTIONS: None.

SIZE: 542

REFERENCES: See Appendix A.2.

```
      FUNCTIONDIF(I,J)
C
C CALCULATE LEQ WITH DIFFRACTION
C
      COMMON/E/S(13),T,DO,ALO(4,13),N(4,13)
      COMMON/G/DELTA,PHI1,PHI2,PP(4,13)
      COMMON/H/XR1(3,13),XR2(3,13),H(4),DC1(4,13),DO2(4,13),
     1DR(4,13),AO1(13),AO2(13),PO(4,13),CC(4),ZO(4),PB
      A1=10.**(ALO(I,J)/10.)
      A2=N(I,J)*DO/T/S(J)/1000.*DO/QO(4)
      A3=DELTAB(PHI1,PHI2)
      DIF=A1*A2*A3
      RETURN
      END
```

D.23 FUNCTION DOT(A,B)

PURPOSE: To calculate the "dot" or scalar product of two vectors (A,B).

SUBPROGRAMS USED: None.

VARIABLES: A(I), B(I) (I=1,2,3); the components of the input vectors.

$DOT = \sum_i A_i B_i$

RESTRICTIONS: The subprogram assumes three-component vectors.

SIZE: 382

REFERENCES: None.

```
                 FUNCTIONDOT(A,B)
           C
           C CALCULATE DOT PRODUCT OF 3-VECTORS
           C
                 DIMENSIONA(3),B(3)
                 DOT=0.
                 DO1001I=1,3
                 DOT=DOT+A(I)*B(I)
           1001  CONTINUE
                 RETURN
                 END
```

D.24 FUNCTION F(PHI)

PURPOSE: To calculate the value of the diffraction function, F, used to evaluate barrier attenuation.

SUBPROGRAMS USED: COS(X), ABS(X), SQRT(X), TAN(X), TANH(X)

VARIABLES:

PHI, the angle between the normal to the barrier-lane system and the point on the lane for which the diffraction function is required.

DELTA, the path length difference between the source location and the receiver.

NBAR, the Fresnel Number for an assumed frequency of 550Hz and a speed of sound of 343 m/s. (2.550/343=3.207)

TPI = $2\pi \simeq 6.2832$

Z1, lower limit criterion for diffraction specified in MAIN. See Appendix A.2.

X3, upper limit for value of attenuation function.

RESTRICTIONS: The theory used to develop this subprogram assumes that the lane and the top edge of the barrier are parallel.

SIZE: 662

REFERENCES: See Appendix A.2.

```
      FUNCTIONF(PHI)
      COMMON/FF/ZAP(4),PI,TPI,Z1,X2,X3,X1,DDD(4,13),DDR(4,13),DDL(4,13)
      COMMON/GOLD/DELTA,PHI1,PHI2,PP(4,13)
      REALNBAR
      NBAR=3.207*DELTA*COS(PHI)
      Y=TPI*ABS(NBAR)
      Y2=SQRT(Y)
      IF(NBAR.LE.Z1)F=1.
      IF((NBAR.LT.0.).AND.(NBAR.GT.Z1))F=X2*TAN(Y2)**2/Y
      IF(NBAR.EQ.0.)F=X2
      IF((NBAR.GT.0.).AND.(NBAR.LT.5.03))F=X2*TANH(Y2)**2/Y
      IF(NBAR.GE.5.03)F=X3
      RETURN
      END
```

D.25 FUNCTION PSI(J,PHI1,PHI2)

PURPOSE: To calculate the integral:

$$PSI = \int_{Y_1}^{Y_2} \cos^{\alpha}(Y)\,dY$$

SUBPROGRAMS USED: COSALP(X), Subroutine QTRA

VARIABLES: Subscript J denotes a lane.

PHI1, PHI2 are integration limits denoting the angular orientation of the lane relative to the receiver.

AUX(10) an auxiliary array used by QTRA.

ALPHA(J), the user-defined value of α relative to lane J from the receiver.

RESTRICTIONS: If α=0, then PSI = PHI2-PHI1. The subprogram assumes that PHI1$\leq$PHI2. Usage reflects this restriction.

SIZE: 534

REFERENCES. See Appendix A.1.

```
      FUNCTIONPSI(J,PHI1,PHI2)
      COMMON/D/ALPHA(13)
      DIMENSIONAUX(10)
      EXTERNALCOSALP
      IF(ALPHA(J).EQ.0.)PSI=PHI2-PHI1
      IF(ALPHA(J).EQ.0.)RETURN
      CALLQATR(PHI1,PHI2,1.E-4,10,COSALP,PSI,IER,AUX)
      RETURN
      END
```

D.26 FUNCTION TPA(X)

PURPOSE: To transform a level (L) to an intensity ($10^{L/10}$)

SUBPROGRAMS USED: None.

VARIABLES: X; the input argument (level, L)

TPA = $10^{X/10}$; the output value (intensity)

RESTRICTIONS: None.

SIZE: 382

REFERENCES: None.

```
FUNCTIONTPA(X)
IF(X.EQ.0.)TPA=0.
IF(X.EQ.0.)RETURN
TPA=10.**(X/10.)
RETURN
END
```

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979 -628-623/2123

FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

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* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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